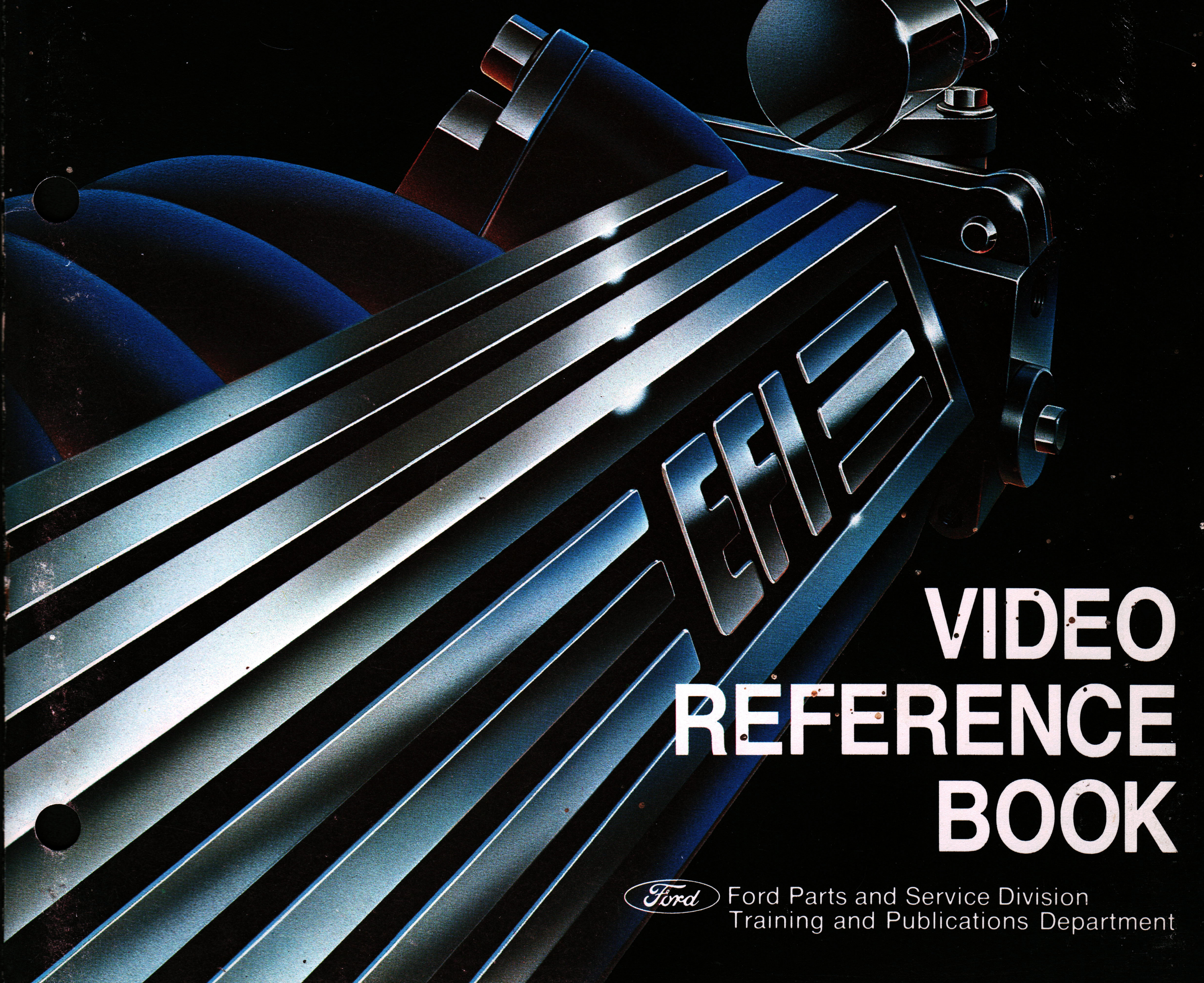
ELECTRONIC FUEL INJECTION

OPERATION AND DIAGNOSIS



VIDEO REFERENCE BOOK

Ford Parts and Service Division
Training and Publications Department

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as for the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across **NOTES**, **CAUTIONS**, and **WARNINGS**. Each one is there for a specific purpose. **NOTES** give you added information that will help you to complete a particular procedure. **CAUTIONS** are given to prevent you from making an error that could damage the vehicle. **WARNINGS** remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general **WARNINGS** that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in under-hood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to insure that the electric cooling fan is completely disconnected when working under the hood.
- Wash hands prior to eating to avoid contaminating food with solvents, sealers, etc. as per instructions on the material container.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design, or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents, if available, may be used. The right is reserved to make changes at any time without notice.

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Produced and Coordinated by
Joseph C. Barney, Jr.
Training and Publications
Department
Ford Parts and Service
Division

TABLE OF CONTENTS

INTRODUCTION 1

OBJECTIVES 3

HISTORY OF FUEL INJECTION 5

BASIC OPERATION 7

BASIC FUEL DELIVERY SYSTEMS 11

- High Pressure In-Tank 11
- Low Pressure In-Tank 13
- Low Pressure In-Tank/High Pressure In-Line 14
- Fuel Reservoir 15
- Fuel System Operation 16
- Inertia Switch 18
- Fuel Lines 19
- Fuel Filter 20
- Fuel Pressure Regulation 21

TYPES OF ELECTRONIC FUEL INJECTION SYSTEMS 23

- Central Fuel Injection (CFI) 25
  - High Pressure Electronic Fuel Injector 26
  - Low Pressure Electronic Fuel Injector 27
  - Fuel Pressure Regulator 28
  - Air Intake 29
- Multi-Point Fuel Injection (EFI) 34
  - High Pressure Electronic Fuel Injector 36
  - Fuel Pressure Regulator 37
  - Air Intake 40

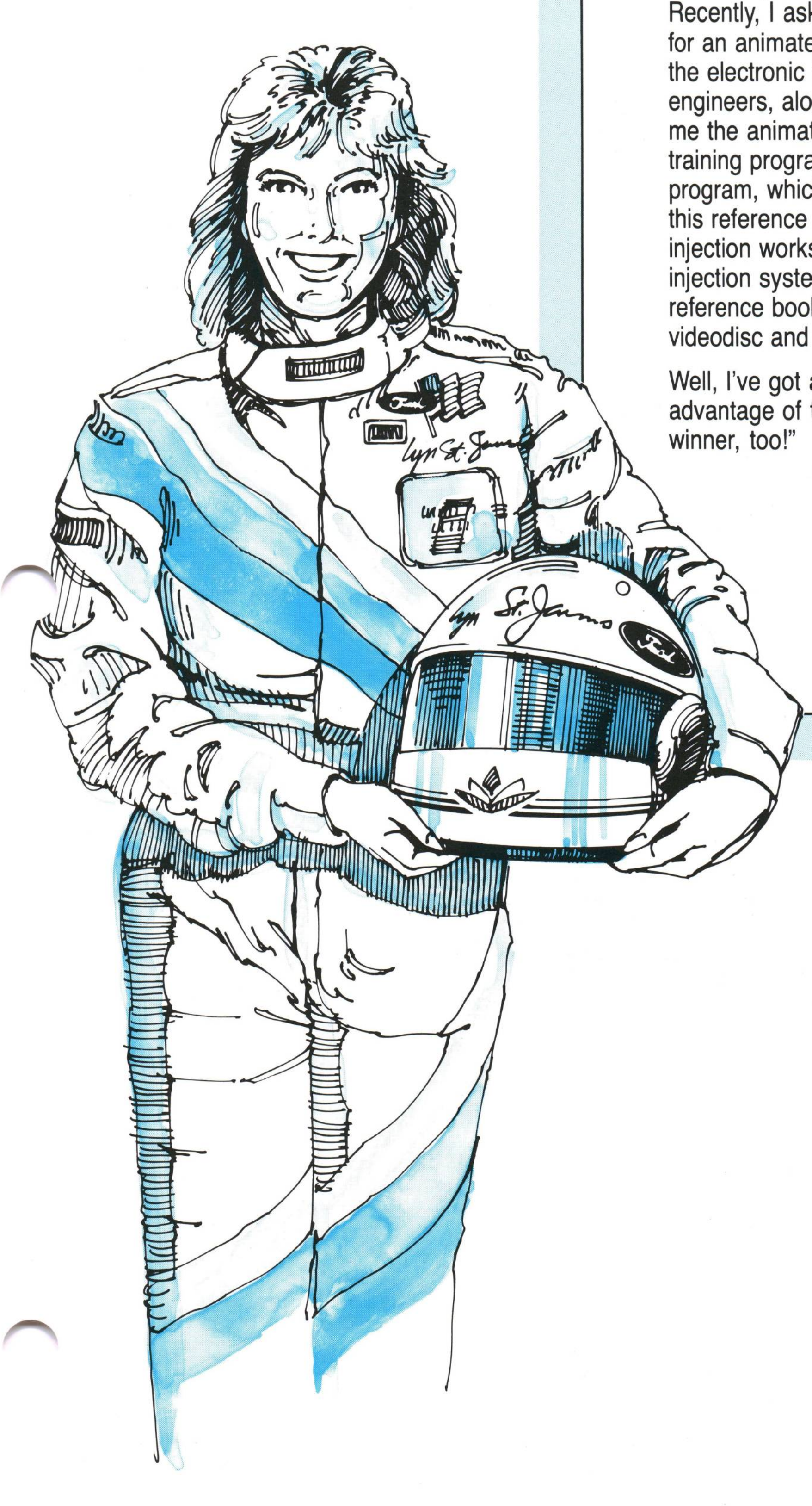
ELECTRONIC ENGINE CONTROL OPERATION 43
Electronic Control Assembly 43
Operating Modes 44
ECA Inputs — Fuel Control 45
Crankshaft Position and Engine RPM 45
Intake Air Temperature 46
Intake Airflow 47
Engine Coolant Temperature 49
Exhaust Gas Oxygen Content 49
EGR Flow Rate 50
Throttle Position 51
Manifold Absolute Pressure and/or Barometric Pressure 52
Actuators (ECA Outputs) — Fuel Control 52
Idle Speed Control 53
CFI Systems 53
Multi-Point (EFI) Systems 54
Switches 55
DIAGNOSIS AND TESTING 59
Inspection 59
Fuel System Checks 60
Pressure and Flow Test 60
Fuel Pressure Regulator Test 64
Rotunda Fuel Injector Tester/Cleaner 64
Description 64
Fuel Injector Testing 66
Fuel Injector Cleaning 68
Fuel Injector Bench Test 69
GLOSSARY OF TECHNICAL TERMS 71

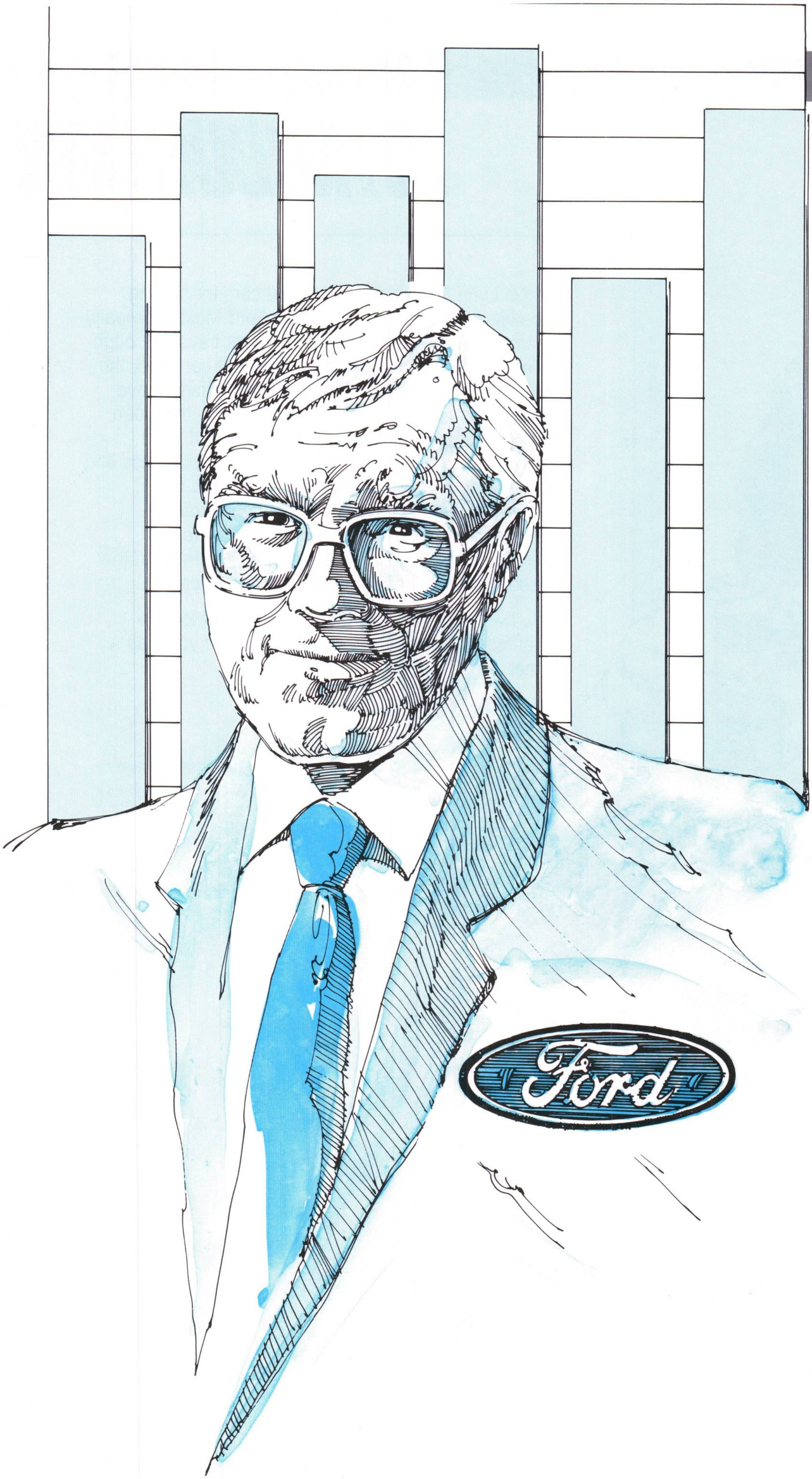
INTRODUCTION

"Hi! I'm Lynn St. James, and I race cars for a living. Recently, I asked the engineers at Ford Motor Company for an animated explanation of how fuel travels through the electronic fuel injection system of my car. Well, the engineers, along with FPSD Technical Training, gave me the animated explanation, and more, in the video training program, 'Electronic Fuel Injection II.' The program, which includes both a two-sided videodisc and this reference book, explains how electronic fuel injection works and covers the high points of fuel injection system diagnosis. You can also use this reference book to review the material presented in the videodisc and to learn more about fuel injection.

Well, I've got a race to win. But remember to take advantage of this training opportunity, and you'll be a winner, too!"

Lyn St. James

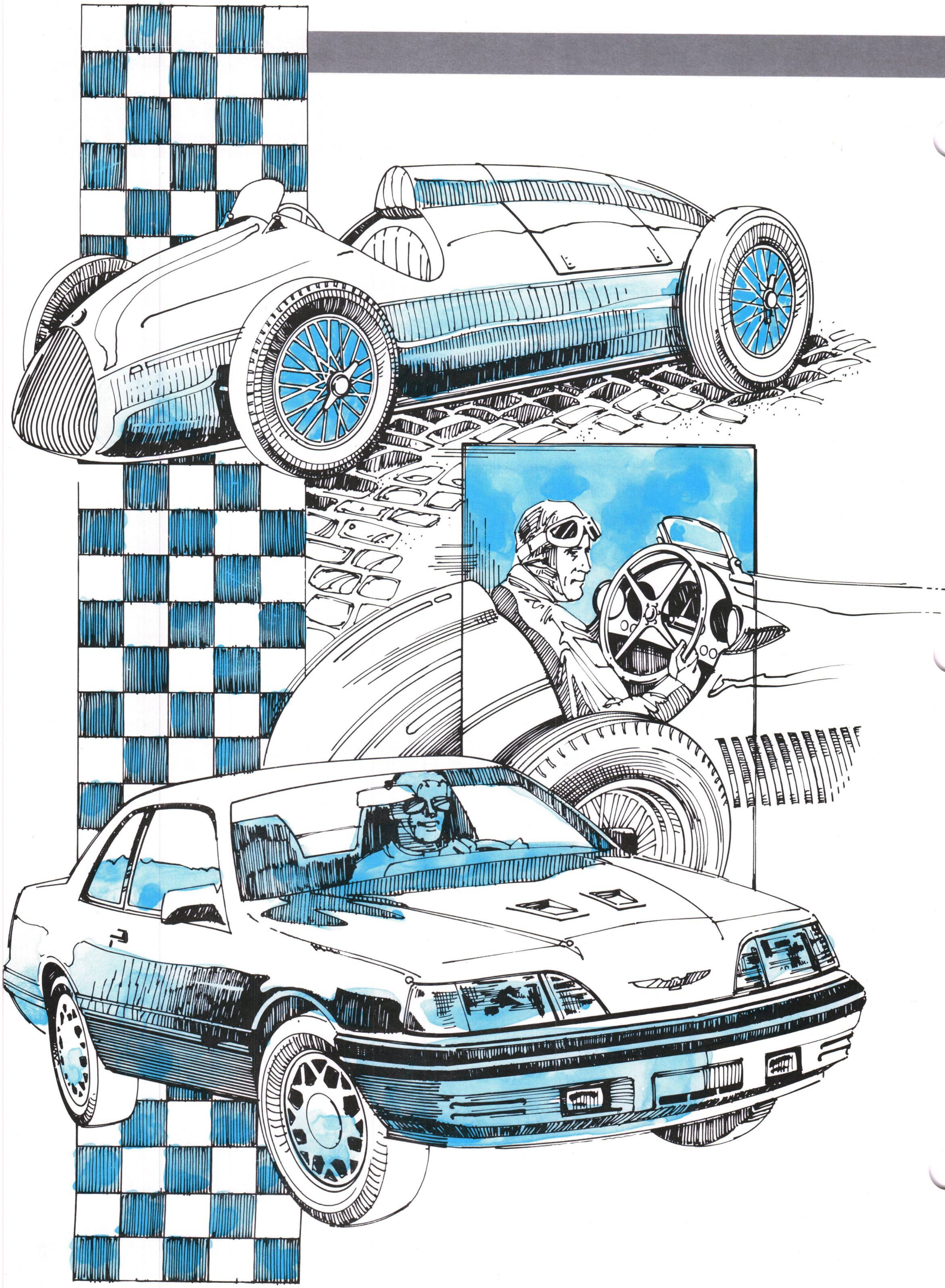



Ford

OBJECTIVES

After studying this technician's reference book you will be able to:

- describe the principles of electronic fuel injection operation.
- identify and locate the correct inspection points for electronic fuel injection systems.
- diagnose an electronic fuel injection system.
- test the fuel pressure and fuel flow of an electronic fuel injection system.
- identify the correct locations for checking fuel pressure and fuel flow on electronic fuel injection systems.
- test and clean electronic fuel injectors using the Rotunda Fuel Injector Tester Cleaner.
- use the test equipment that is required when working on an electronic fuel injection system.
- identify the components of an electronic fuel injection system.
- explain the operation of each of the major electronic fuel injection system components.



HISTORY OF FUEL INJECTION

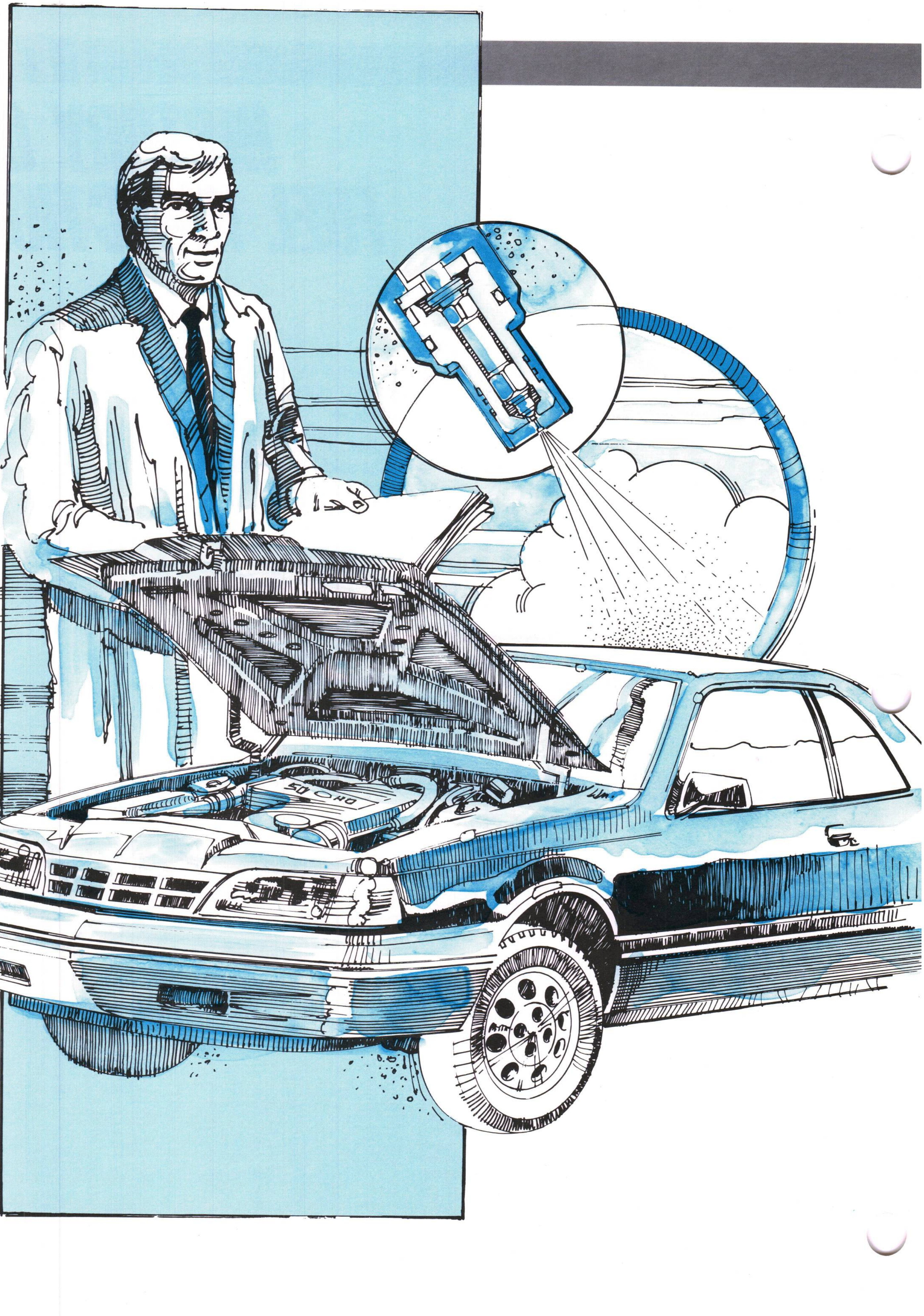
Experiments with fuel injection began in 1912, resulting in fuel injected engines for aircraft in 1932, and for race cars in the 1940's. It was not until 1957 that a fuel injected engine was introduced on a domestic production automobile.

Two events caused a new surge of interest in fuel injected engines: the federal government established fuel efficiency standards for automobiles sold in the United States; and, a rapid expansion of the electronics industry resulted in the availability of reliable and inexpensive solid-state electronic components, making fuel injection more affordable to consumers.

Automobile manufacturers realized that existing fuel systems, using carburetors which were already increasing in both complexity and cost, would have trouble meeting future government standards. Therefore taking advantage of new technology, they introduced computer control of electronic fuel injection and emission controls.

In 1975 the electronic fuel injection system reappeared in a domestic vehicle. Today, all domestic manufacturers offer electronic fuel injection on most vehicles. These systems represent the most precise fuel systems ever developed for the automobile.

In 1980 Ford Motor Company introduced electronic fuel injection on the 5.0L engine. Today, Ford has expanded electronic fuel injection usage.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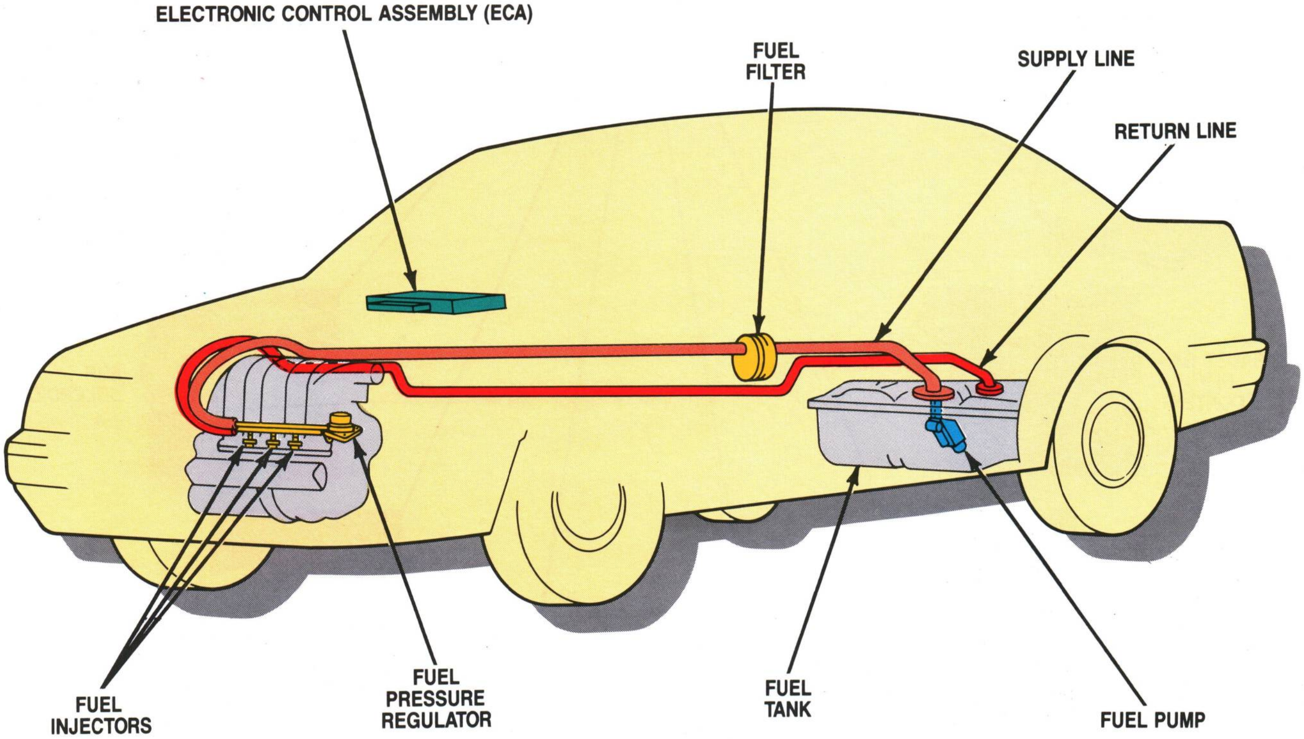
BASIC OPERATION



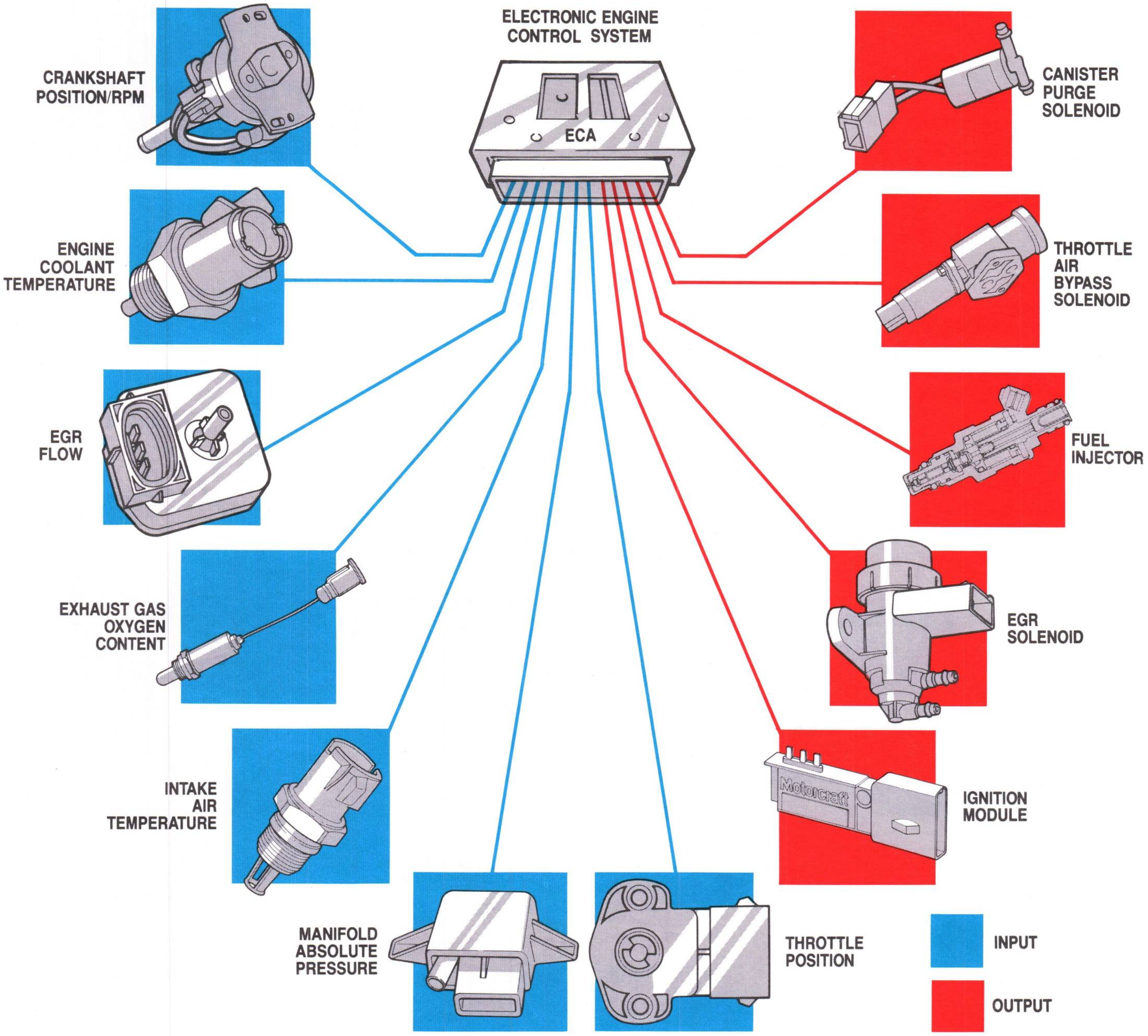
Fuel Injection Schematic

Electronic fuel injection, like carburetion, is a way of delivering the correct air/fuel mixture to the engine at the correct time under all operating conditions. Electronic fuel injection is much more precise than carburetion, however, because it is controlled electronically, rather than mechanically.

When the ignition is switched on, fuel is pumped from the fuel tank, through a filter, and then through a supply line to the fuel injectors at the engine. Each injector sprays fuel into the intake air as the air travels toward the combustion chamber.

Fuel pressure across the injectors is maintained by a pressure regulator. Because fuel pressure is a constant while fuel demand is not, the system includes a fuel return line which allows excess fuel to flow back through the regulator to the fuel tank.

BASIC OPERATION

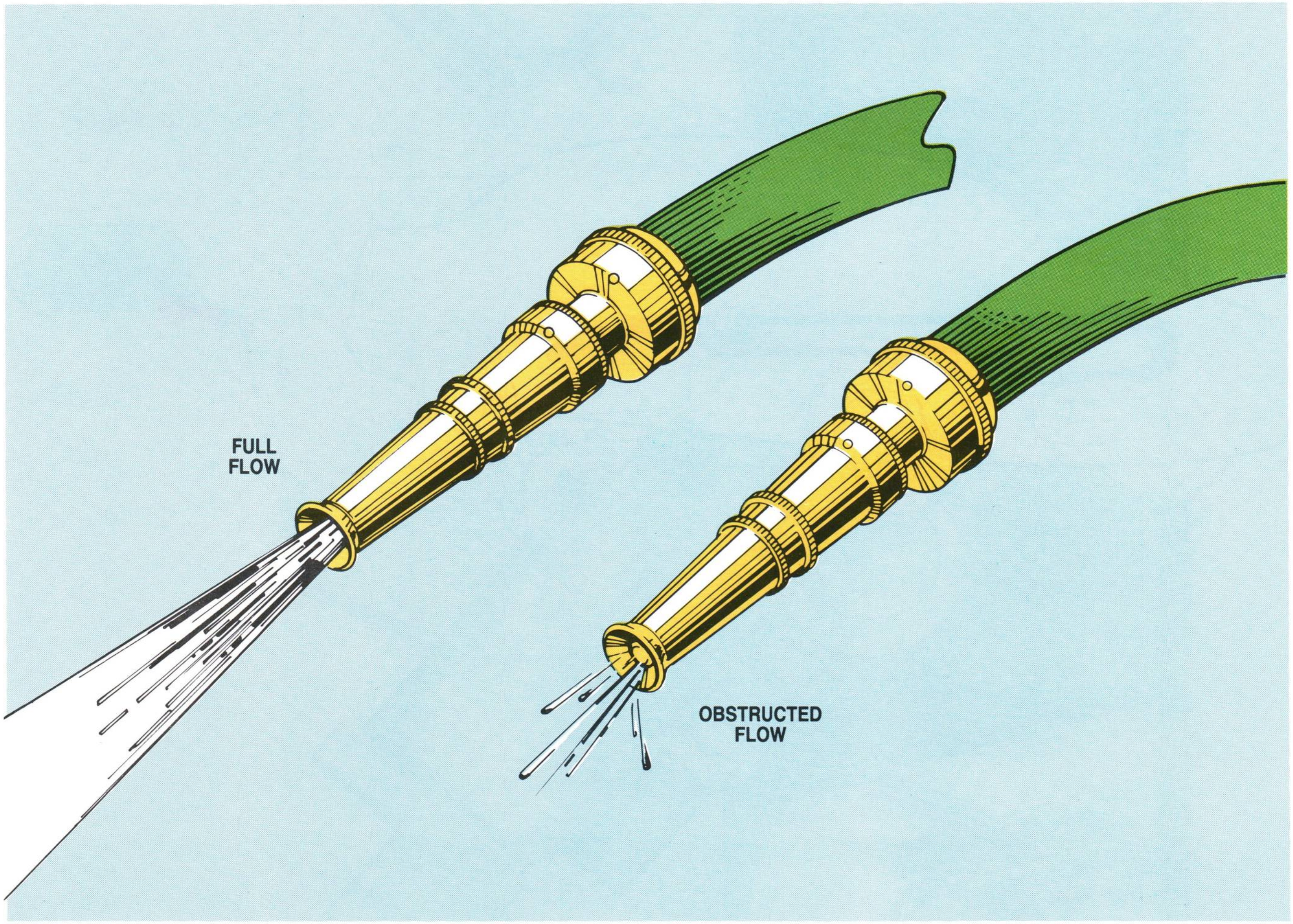


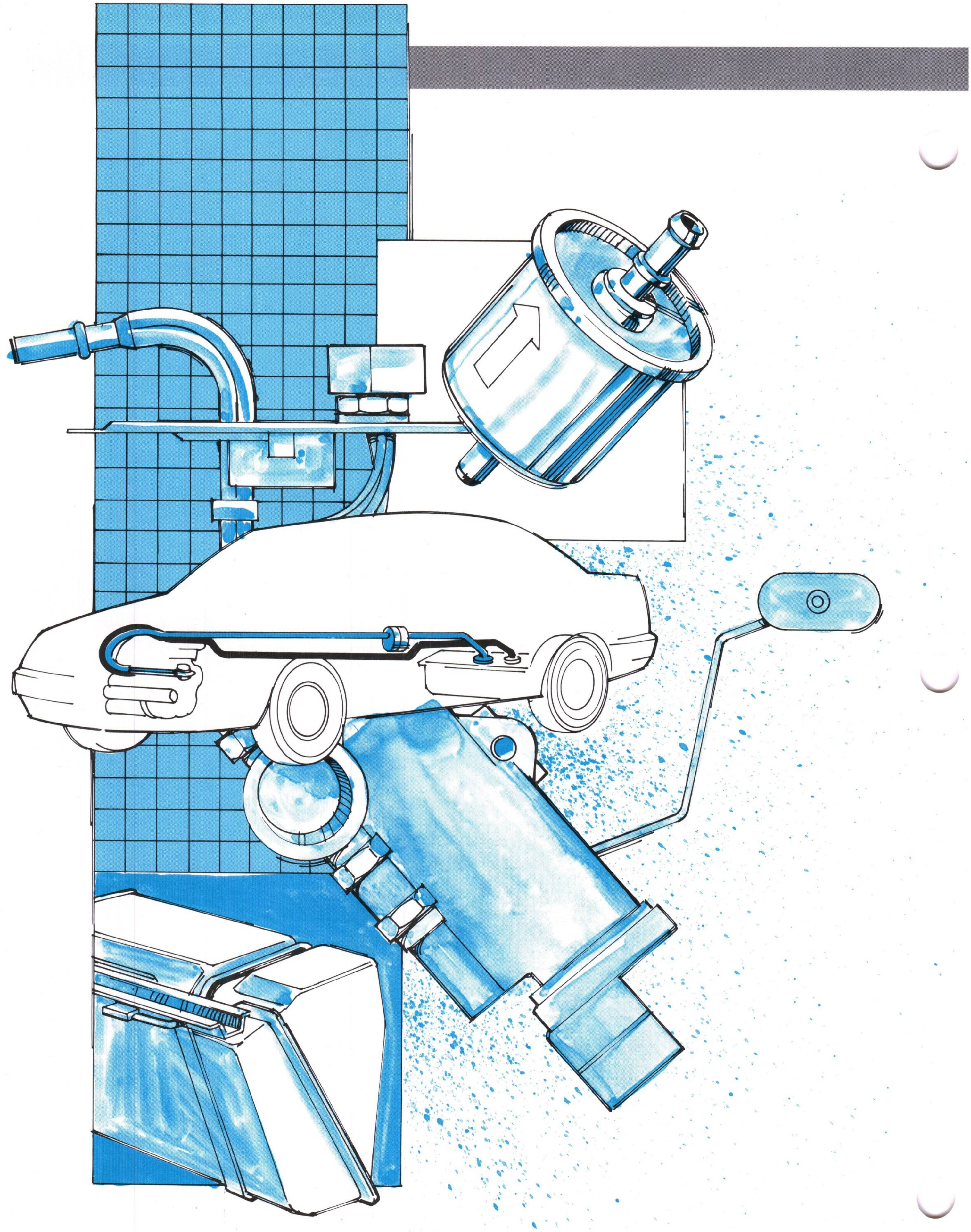
The amount of fuel the injectors will spray under a particular operating condition is determined by an electronic control assembly (ECA). This assembly receives electrical signals from sensors that monitor factors such as airflow to the engine, engine coolant temperature, engine vacuum conditions, etc. The ECA evaluates the sensor information, and based on this, signals the fuel injectors, thereby controlling their on-and-off "pulses." The amount of time that an injector is operating (spraying) is called injector "pulse width" or injector "on time". In this book it will be referred to as pulse width.

The precision control of the electronic fuel injection system allows the engine to operate with an optimum air/fuel ratio throughout its entire RPM range and under all operating conditions. This results not only in high engine performance, but in the lowest possible levels of unburned hydrocarbons, carbon monoxide and nitrogen oxides in the exhaust gases.

As you might expect though, a precision system requires precision care. Electronic fuel injected engines are more sensitive to dirt than carbureted engines. The recommended gasoline must always be used to keep the fuel injectors clean. Dirt must not reach the fuel injectors!

Remember, a fuel injector acts like a nozzle on a garden hose — only it's much smaller. If dirt or grit clogs the nozzle opening, fuel may not flow properly, causing the engine to run roughly, deliver less power, or even stall.





BASIC FUEL DELIVERY SYSTEMS

Ford Motor Company uses three different electronic fuel injection systems, depending on vehicle application:

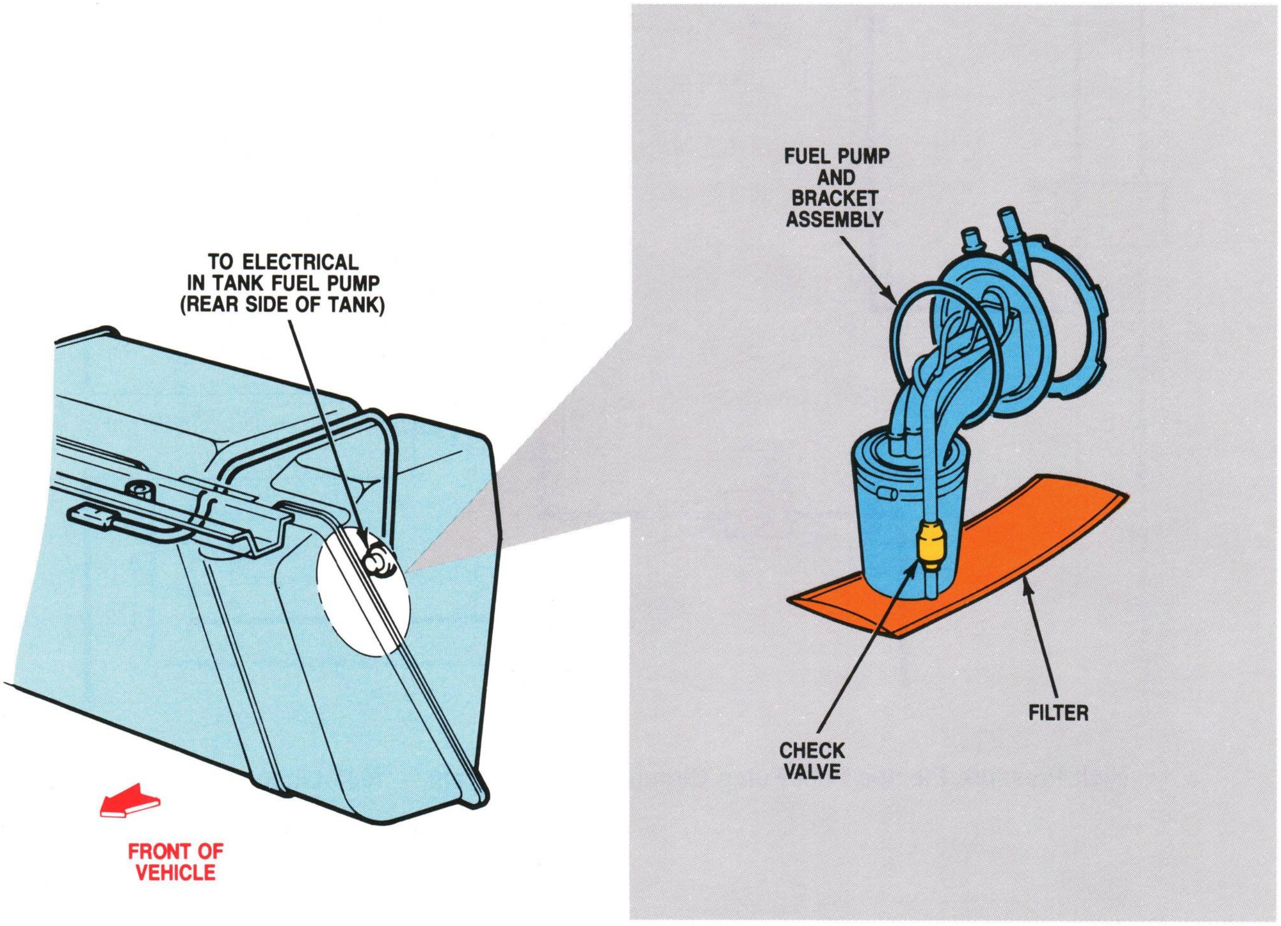
- High pressure in-tank
- Low pressure in-tank
- Low pressure in-tank/high pressure in-line

HIGH PRESSURE IN-TANK SYSTEM

In this system a high pressure electric fuel pump is located in the sump in the fuel tank. This sump allows the pump to operate effectively during extreme vehicle maneuvers and with low tank fuel levels.

The high pressure in-tank fuel pump can supply 60.0-100.0L (15.9-26.25 gallons) of fuel per hour at a working pressure of 269 kPa (39 psi). The pump has an internal relief valve to provide overpressure protection in the event the fuel flow becomes restricted (clogged or damaged fuel filter, etc.). Overpressure is limited to 850 kPa (123 psi), and reduced fuel flow results.

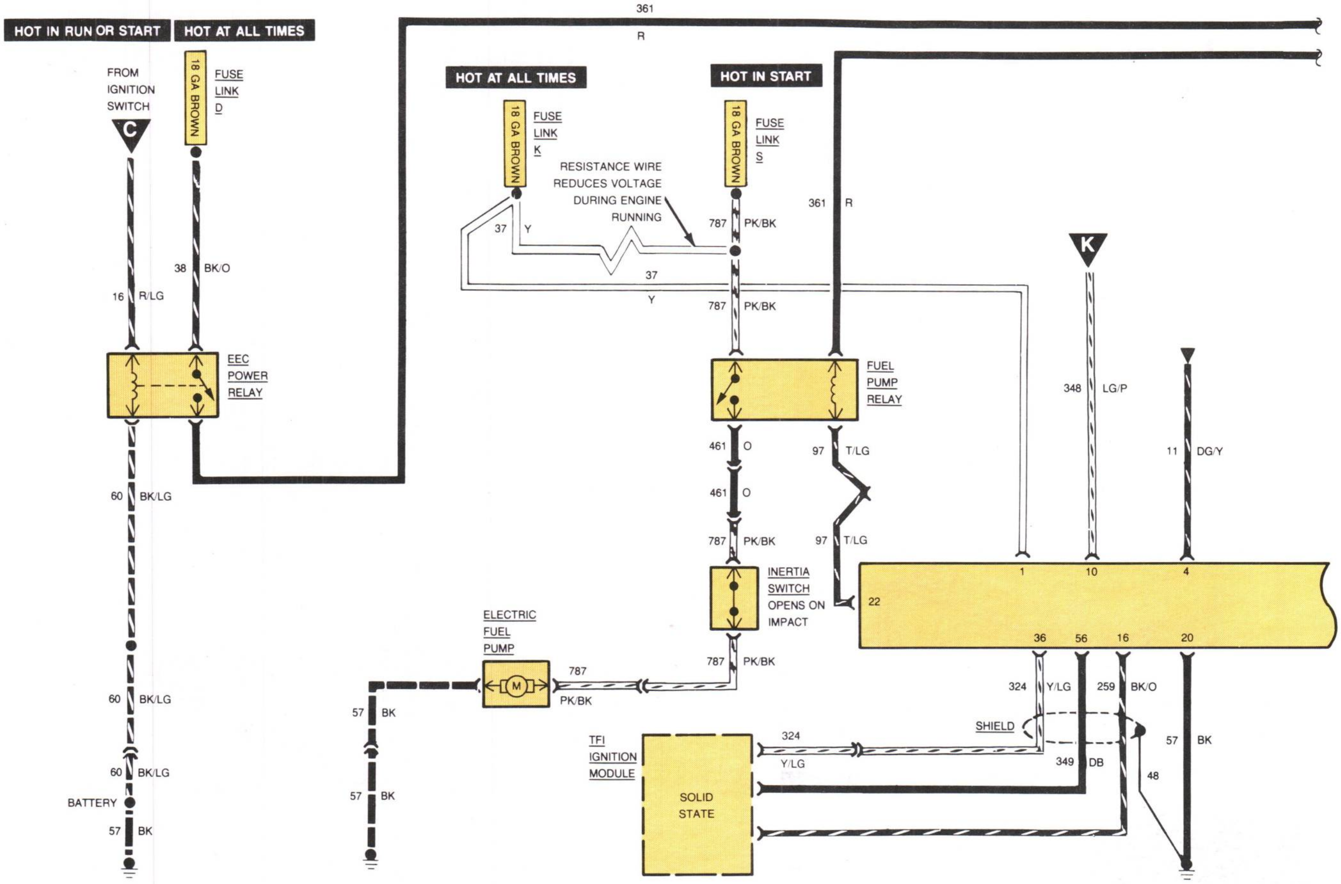
The fuel pump is protected at its inlet by a nylon pickup element. This nylon element filters dirt and contaminants which could plug or damage the internal pump components.



High Pressure In-Tank Electric Fuel Pump

BASIC FUEL DELIVERY SYSTEMS

In most high pressure in-tank fuel systems, battery voltage is applied to the fuel pump whenever the fuel pump relay is energized. Battery voltage is applied when the ignition switch is in the START position. In the RUN position, power to the fuel pump goes through a resistor to drop the voltage to approximately 9 volts. This reduces the fuel pump noise that can he heard inside the vehicle's passenger compartment.



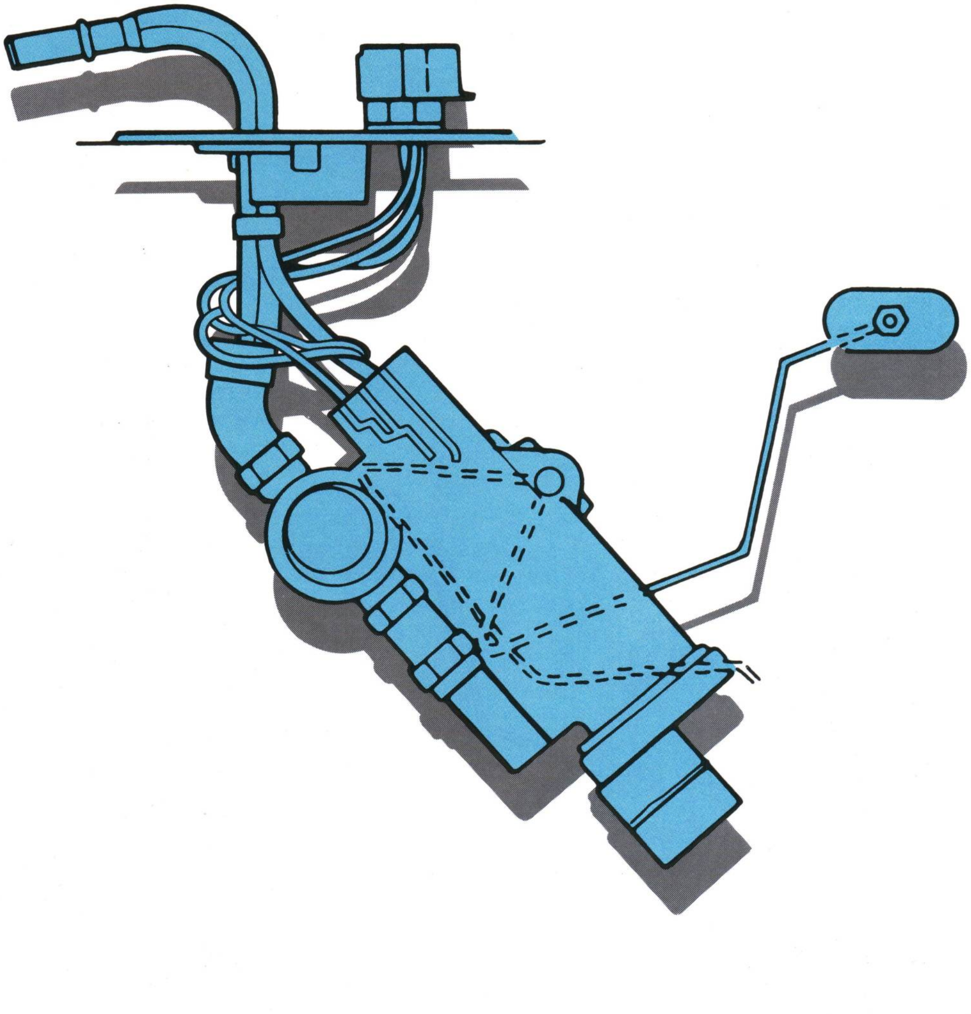
High Pressure Electric Fuel Pump Circuit Wiring Diagram — 1987 Lincoln Town Car

LOW PRESSURE IN-TANK

In this system a low pressure (instead of a high pressure) electric fuel pump is located in the sump of the fuel tank. The sump allows effective pump operation during extreme vehicle maneuvers and with low tank fill levels.

The fuel pump is mounted on the fuel sender assembly inside the fuel tank. This assembly includes a check valve located between the fuel pump and the outlet tube of the assembly. This valve maintains pressure in the system after the vehicle is shut down, thereby helping to prevent hot starting problems. The pump can supply up to 64 liters (16.9 gallons) of fuel per hour at 110 kPa (15.9 psi). The fuel pump does not have an internal pressure relief valve. However, the maximum pressure the unit will produce is limited to 260 kPa (37.7 psi). The system pressure is controlled by a pressure regulator on the engine.

The fuel pump is protected at its inlet by a nylon pickup element. This nylon element filters dirt and contaminants which could plug or damage the internal pump components.



Low Pressure In-Tank Electric Fuel Pump

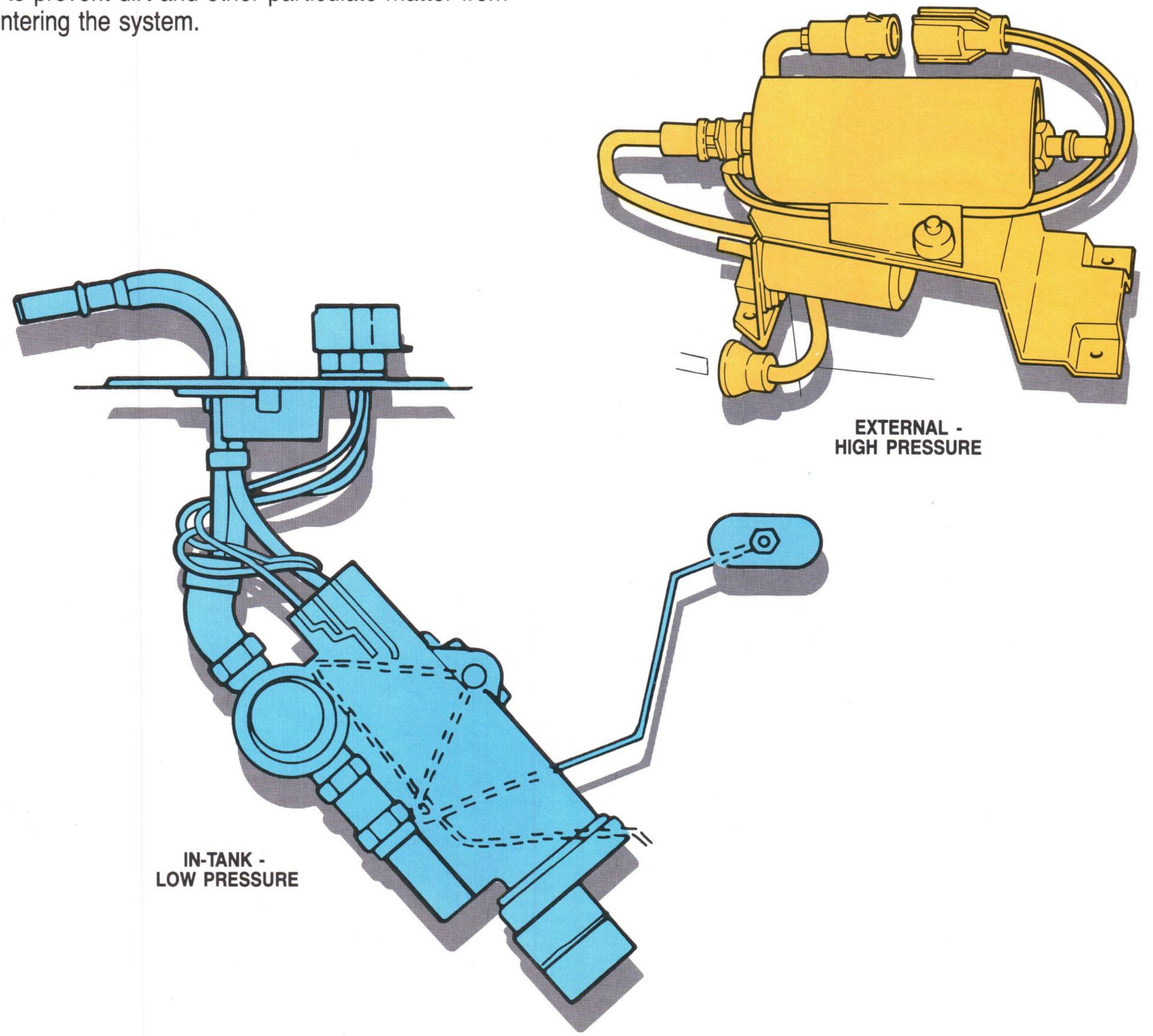
LOW PRESSURE IN-TANK/HIGH PRESSURE IN-LINE

In this system two electric fuel pumps are used: a low pressure boost pump located in the fuel tank, and a high pressure fuel pump located on the frame rail, in-line between the low pressure in-tank pump and engine fuel charging assembly.

The low pressure pump is positioned with its inlet at the bottom of an internal sump in the fuel tank. This design allows the pump to operate effectively during extreme vehicle maneuvers and with low tank fill levels.

The low pressure electric fuel pump provides pressurized fuel to the inlet of the high pressure pump and helps prevent noise and heating problems. The inlet of the low pressure fuel pump has a nylon filter on it to prevent dirt and other particulate matter from entering the system.

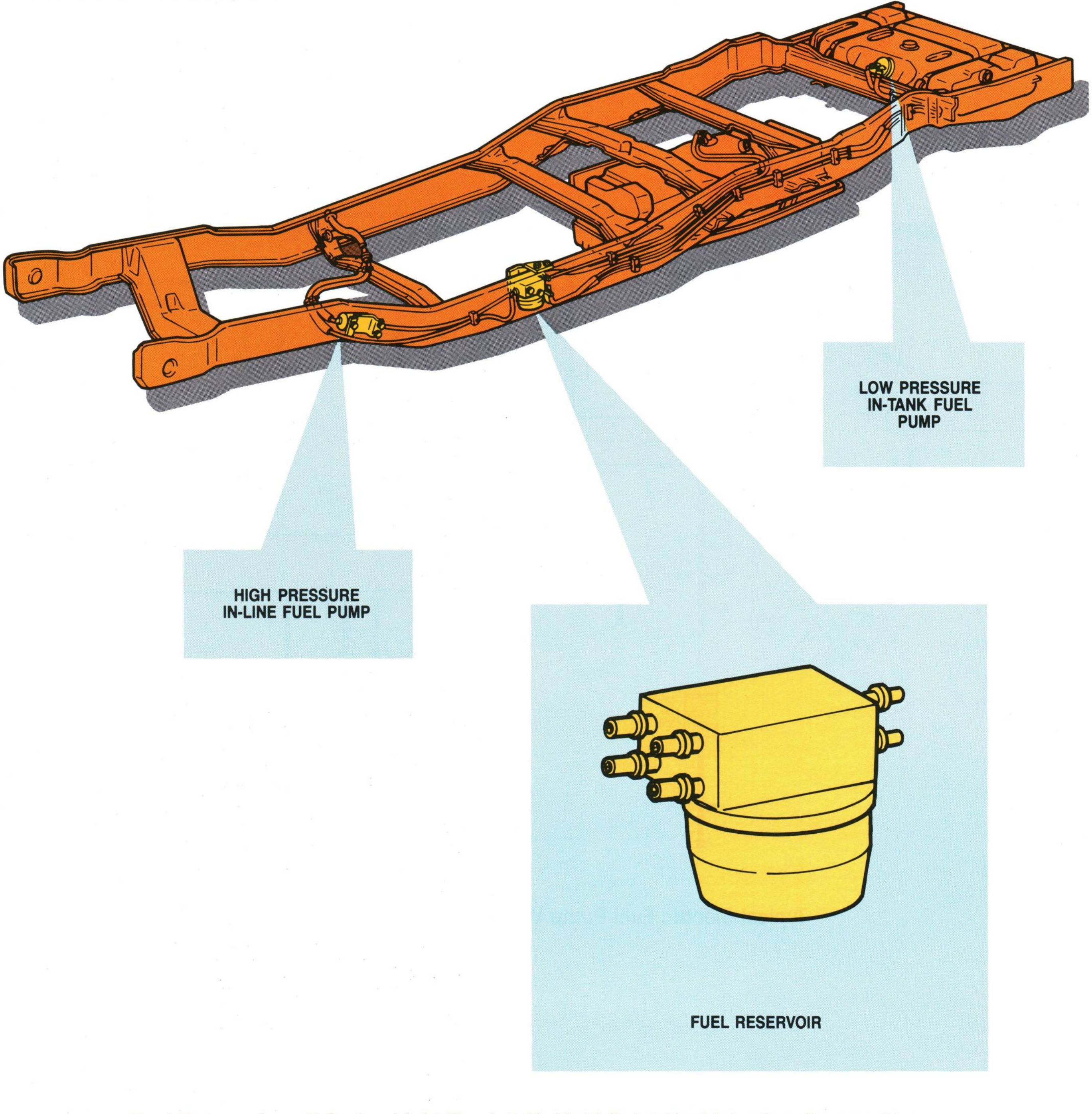
The externally mounted high pressure fuel pump can supply up to 60 liters (15.9 gallons) of fuel per hour at a working pressure of 269.0 kPa (39 psi). The pump has an internal pressure relief valve to provide overpressure protection in the event the fuel flow becomes restricted. Overpressure is restricted to 850 kPa (123 psi), and reduced fuel flow results. The system pressure is controlled by a pressure regulator on the engine.



Low Pressure In-Tank/High Pressure In-Line Electric Fuel Pump

FUEL RESERVOIR

Some low pressure in-tank/high pressure in-line systems have a fuel reservoir located between the low pressure in-tank electric fuel pump and the high pressure in-line electric fuel pump. This reservoir provides fuel to the system during extreme operating conditions such as wide-open throttle.


LOW PRESSURE IN-TANK FUEL PUMP
HIGH PRESSURE IN-LINE FUEL PUMP
FUEL RESERVOIR

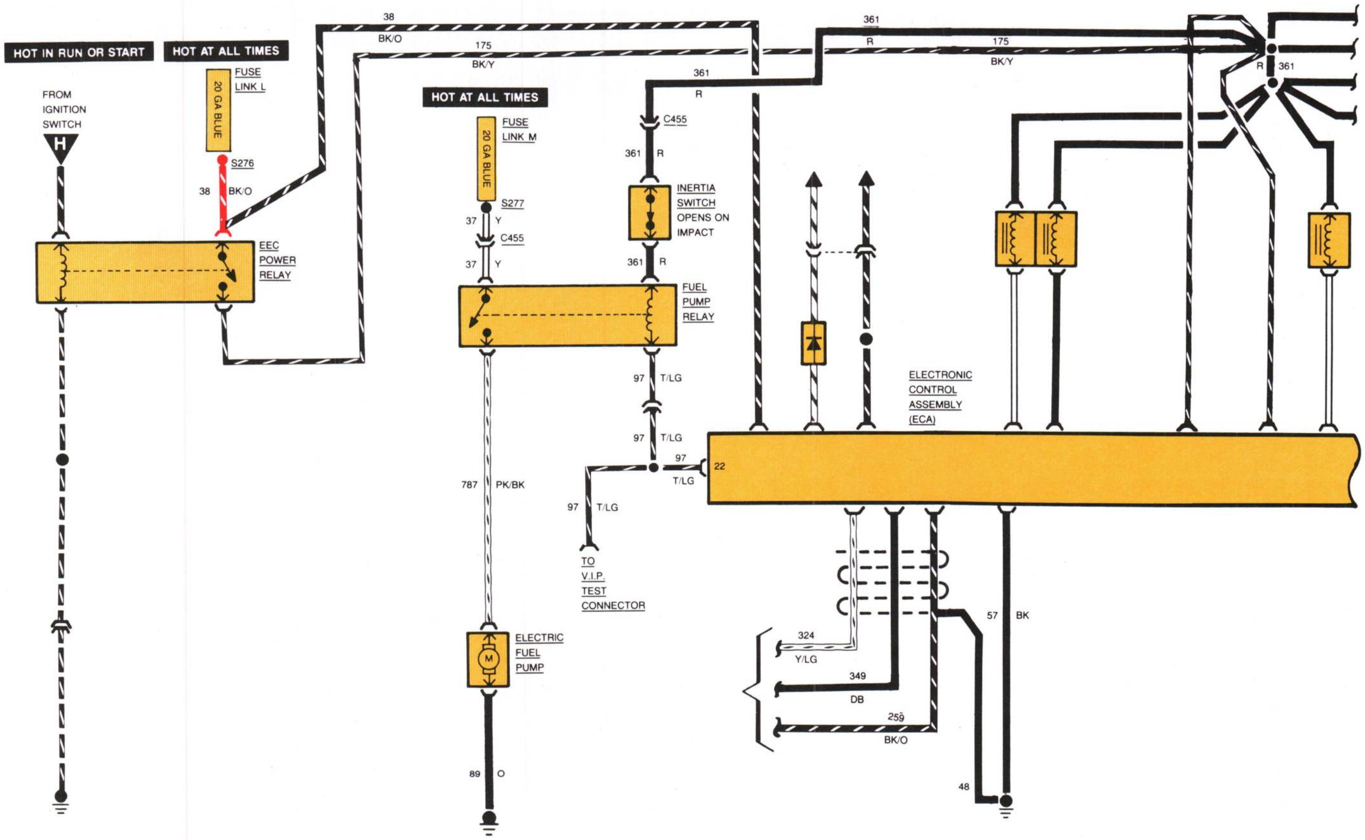
Fuel Reservoir — F-Series Light Truck-5.0L Multi-Point Fuel Injection System Shown — Others with Reservoir are Similar

FUEL SYSTEM OPERATION

The three fuel systems operate electrically in the same way. The electrical system provides power to the fuel pump(s) through two relays: the electronic engine control (EEC) power relay, and the fuel pump relay. The current path is dependent upon vehicle application.

When the ignition switch is off, the contacts of both relays are open.

When the ignition switch is first turned to the ON position, the EEC power relay is energized, thus closing its contacts. Current flows through the EEC power relay to the coil side of the fuel pump relay. When the electronic control assembly (ECA) receives a signal on pin 1, it supplies a ground to the fuel pump relay, allowing current to go through the fuel pump relay to the fuel pump(s).

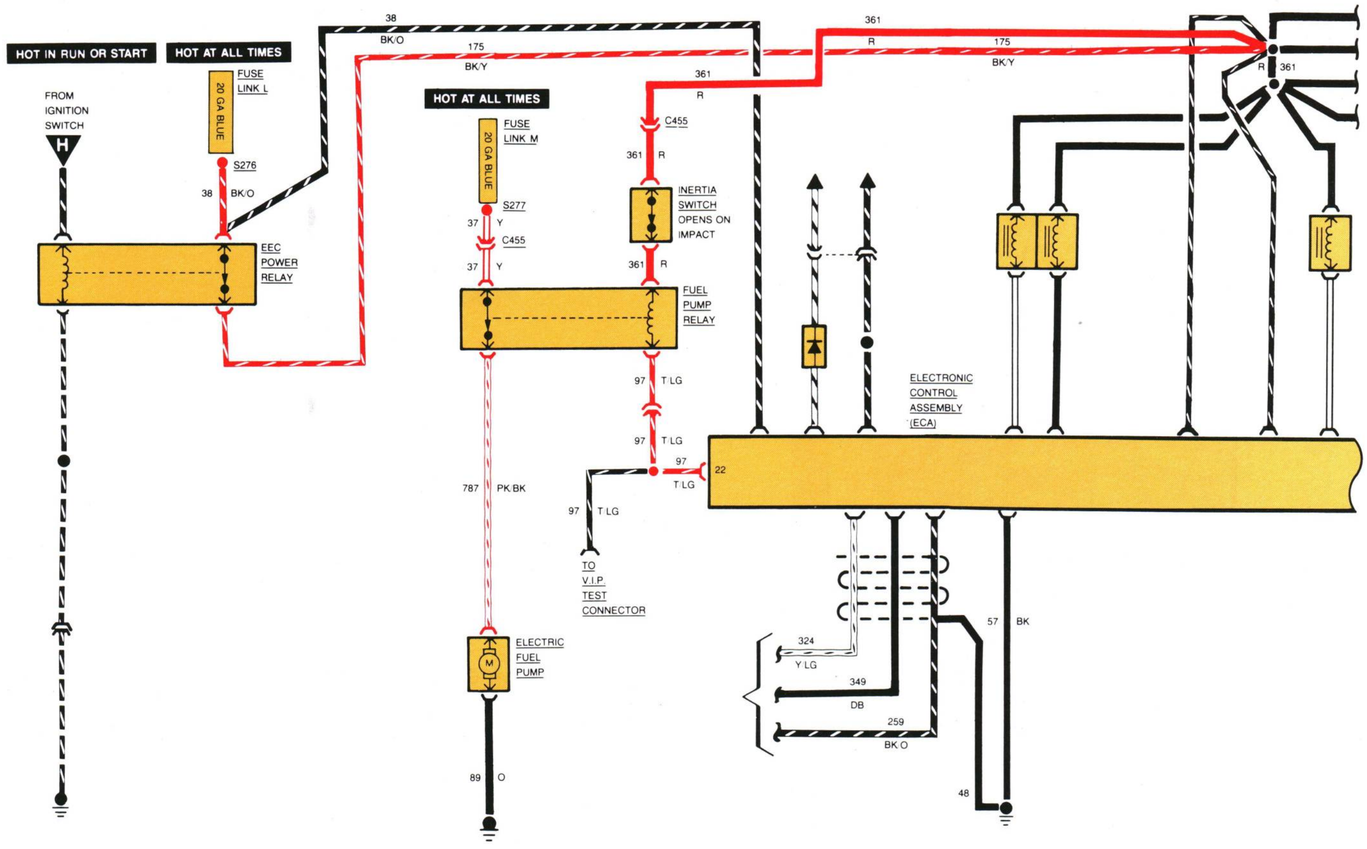


Typical Electric Fuel Pump Wiring — Ignition OFF

If the ignition switch is not turned to the START position, the ECA will open the ground circuit (after approximately 1-2 seconds) to the fuel pump relay. Opening the ground circuit de-energizes the fuel pump(s). This provides for pre-pressurization of the fuel system.

When the ignition switch is turned to the START position, the ECA grounds the fuel pump relay, allowing the fuel pump(s) to operate while cranking.

After the engine starts and the ignition switch is turned to the ON position, power is supplied to the fuel pump(s) until the ECA senses engine RPM dropping below 120 RPM, or the ignition switch is turned to the OFF position. The ECA then reopens the ground circuit to the fuel pump relay.



Typical Electric Fuel Pump Wiring — Ignition ON

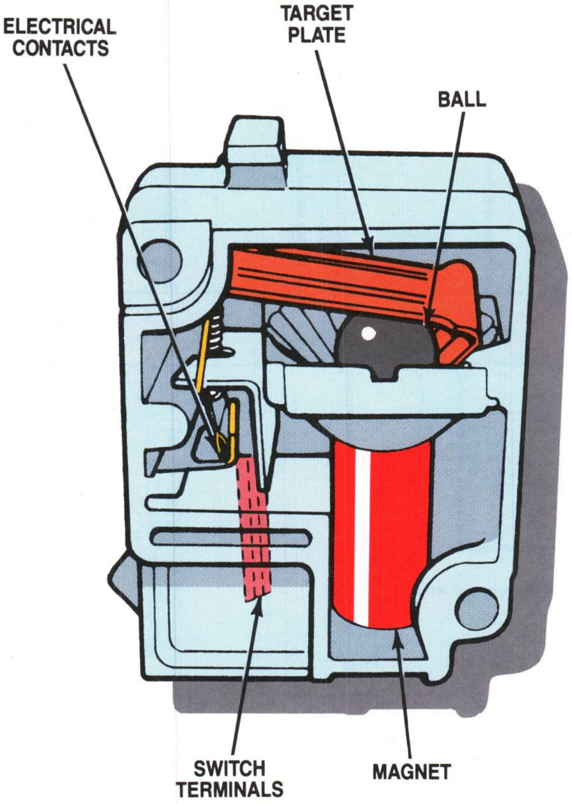
INERTIA SWITCH

On all Ford electronic fuel injected engines, an inertia switch is placed in series between the fuel pump relay and the fuel pump(s), or before the fuel pump relay. In either location, the inertia switch serves the same purpose, that is, to open the power circuit to the fuel pump(s), or the control circuit to the fuel pump relay, in case of an accident.

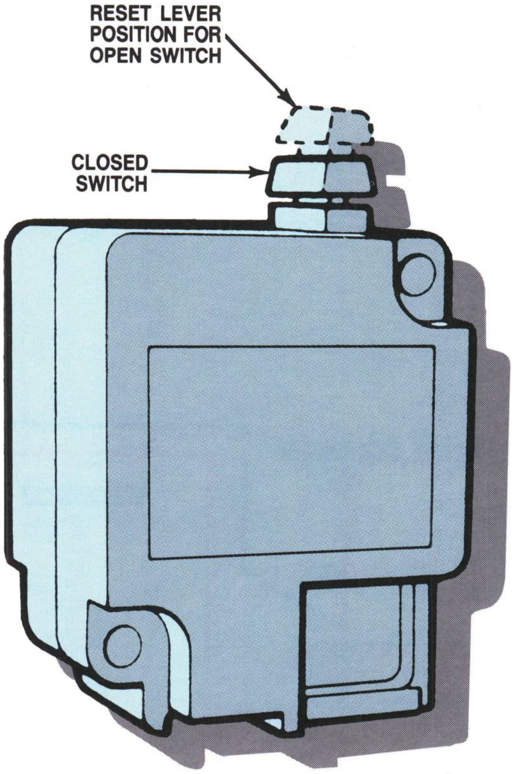
The inertia switch must be manually reset by pushing the reset button located on top of the inertia switch.

WARNING

IF YOU SEE OR SMELL GASOLINE, DO NOT RESET THE INERTIA SWITCH BUTTON.



Typical Inertia Switch Operation



Typical Inertia Switch

Operation of the inertia switch is as follows:

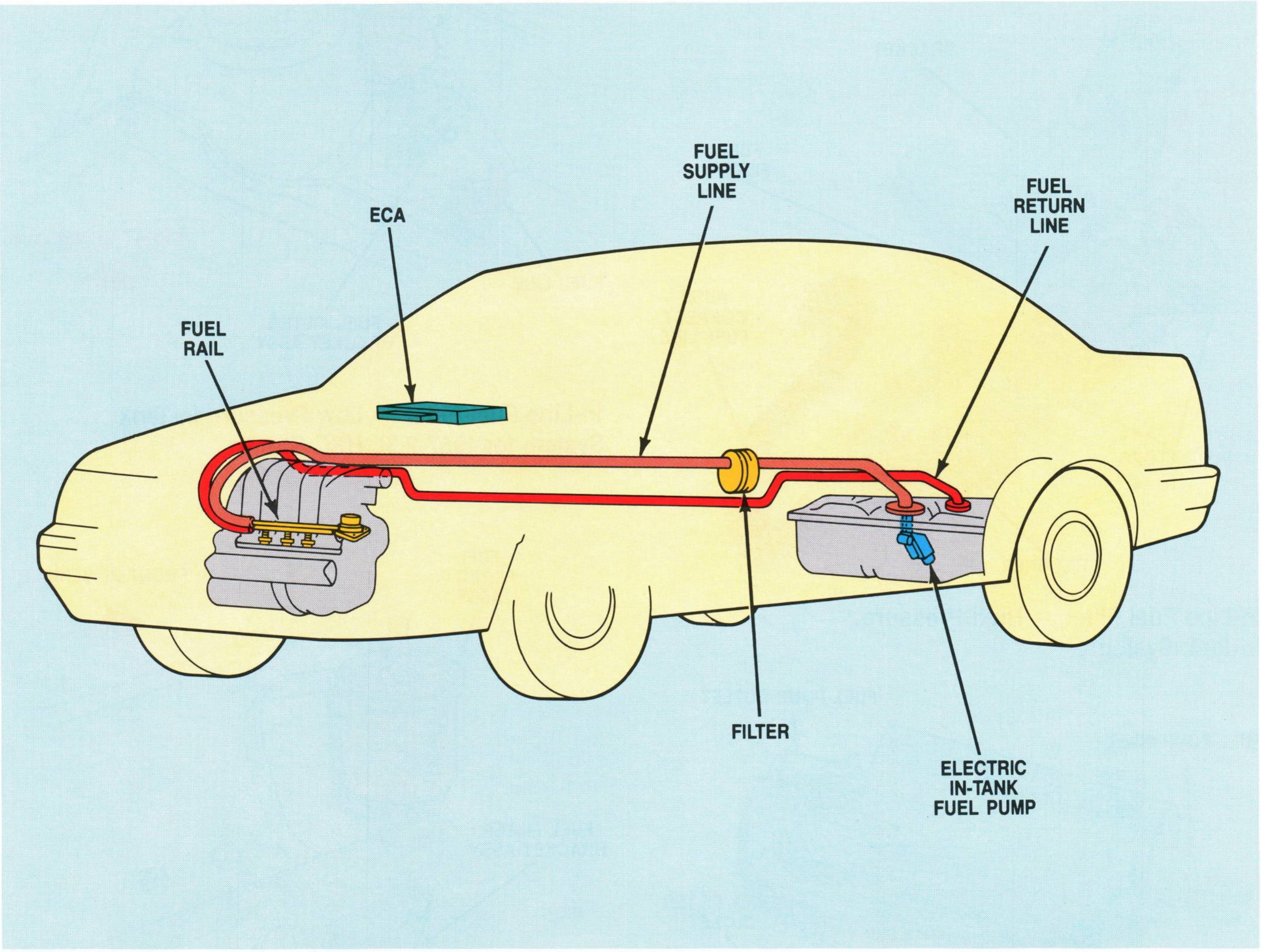
A steel ball is held in place by a magnet. When a sharp impact occurs, the ball breaks loose from the magnet, rolls up a conical ramp and strikes a target plate, which opens the electrical contacts.

NOTE

A voltage drop test across the inertia switch connector should show 0.30 volt or less on an operative system.

FUEL LINES

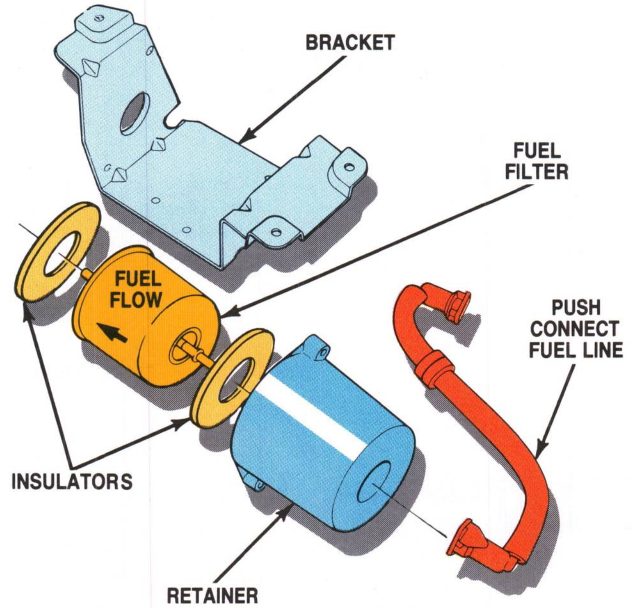
The system requires two fuel lines. A supply line (through the filter) connects the fuel pump(s) to the fuel rail (EFI) or fuel charging assembly (CFI). A return line allows excess fuel supplied by the pump(s), but not needed by the engine, to be returned to the fuel tank or to the reservoir, if so equipped.



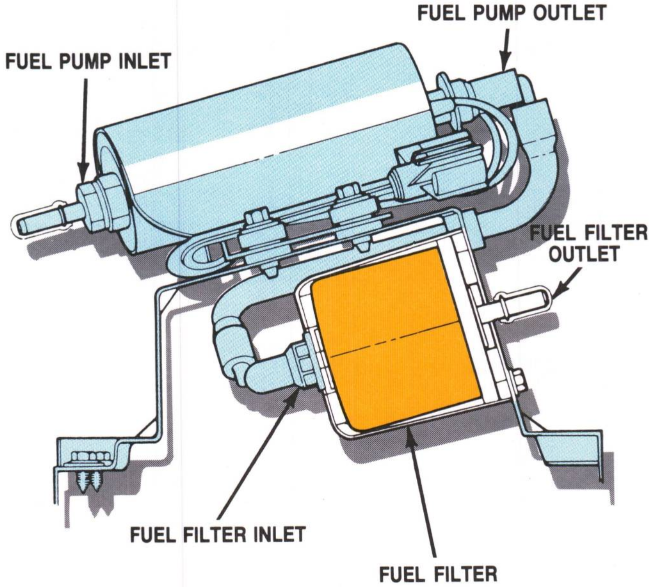
Typical Fuel System — EFI System

FUEL FILTER

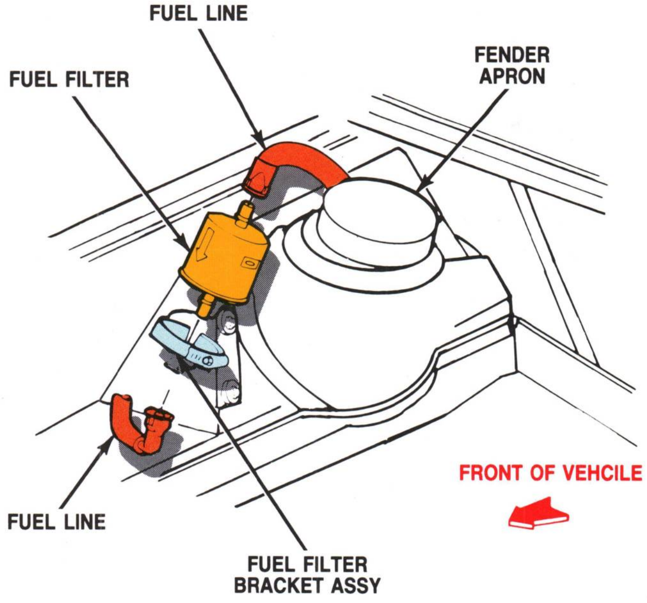
A fuel filter is installed in-line between the fuel tank and the engine fuel charging assembly. This filter traps dirt or contaminants before they reach the fuel injector(s). Extremely clean fuel is a requirement of a fuel injected engine, due to the small fuel passages through the fuel injector(s).



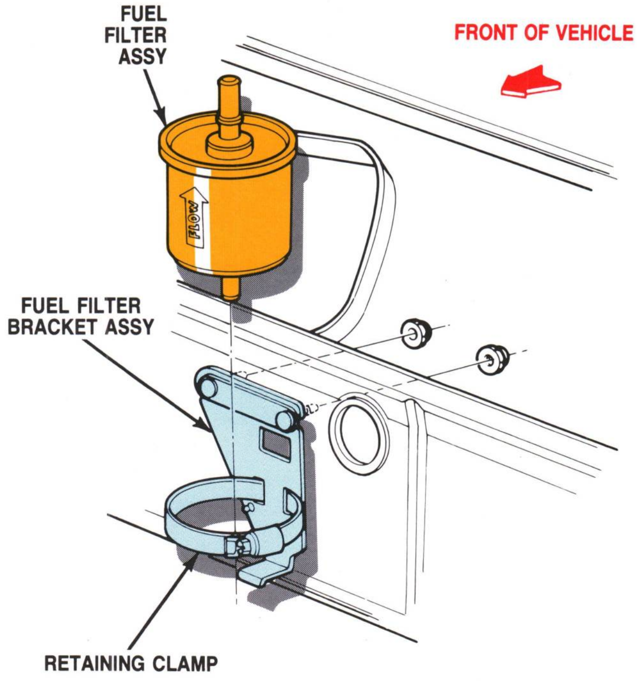
In-Line Fuel Filter — High Pressure In-Tank System



In-Line Fuel Filter — Low Pressure In-Tank/High Pressure In-Line System



In-Line Fuel Filter — Low Pressure In-Tank System for 1987 2.3L HSC Shown

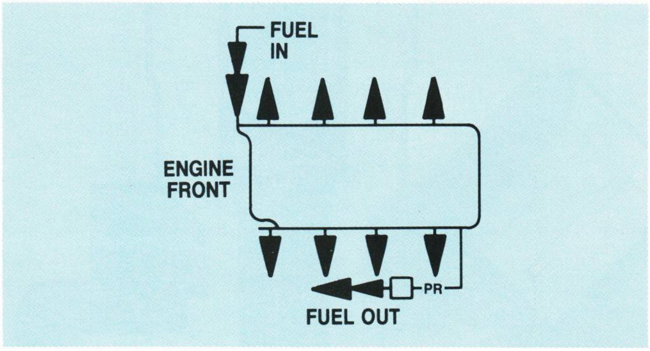


In-Line Fuel Filter — Low Pressure In-Tank System and High Pressure In-Tank System for Escort CFI and EFI Applications

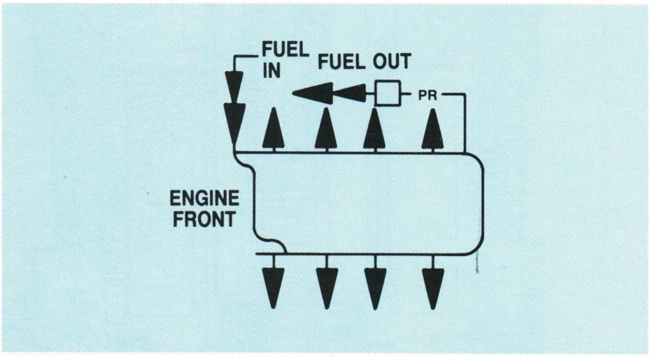
FUEL PRESSURE REGULATION

A fuel pressure regulator maintains a constant pressure drop across the injectors. The regulator is connected in series with the fuel injectors, and is positioned upstream or downstream of the injectors depending on vehicle application. Excess fuel supplied by the fuel pump(s), but not required by the engine, passes through the regulator and returns to the fuel tank by way of the fuel return line.

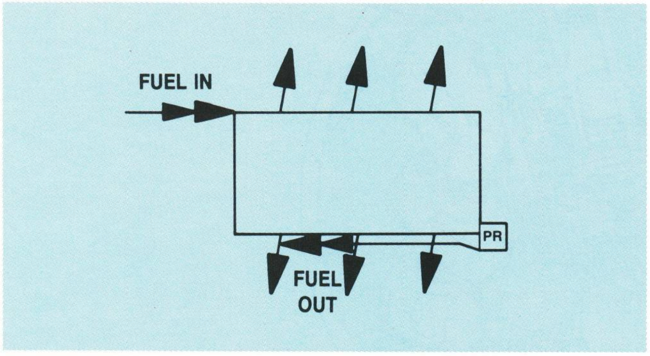
Ford Motor Company uses two types of fuel pressure regulators. Their operation is explained in the following pages under Central Fuel Injection (CFI) —Fuel Pressure Regulator, and Multi-Point Fuel Injection (EFI) — Fuel Pressure Regulator.



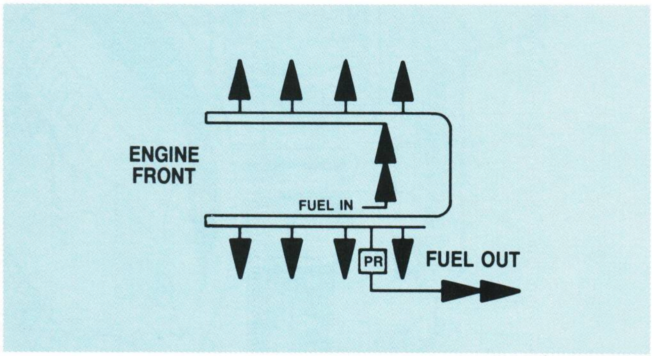
V8 (CAR)



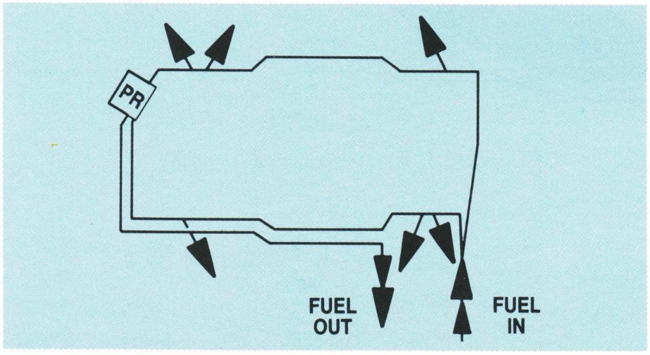
V8 (CAR)



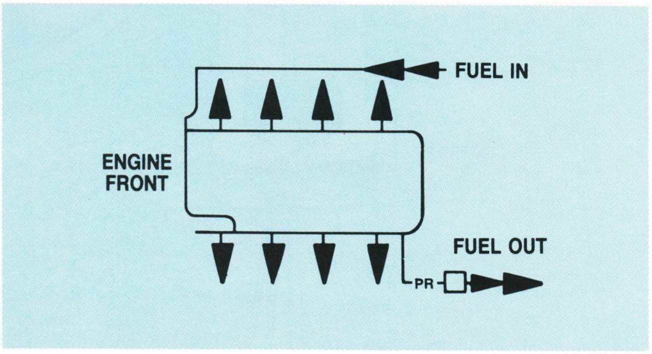
V6



V8 (TRUCK – AIR)

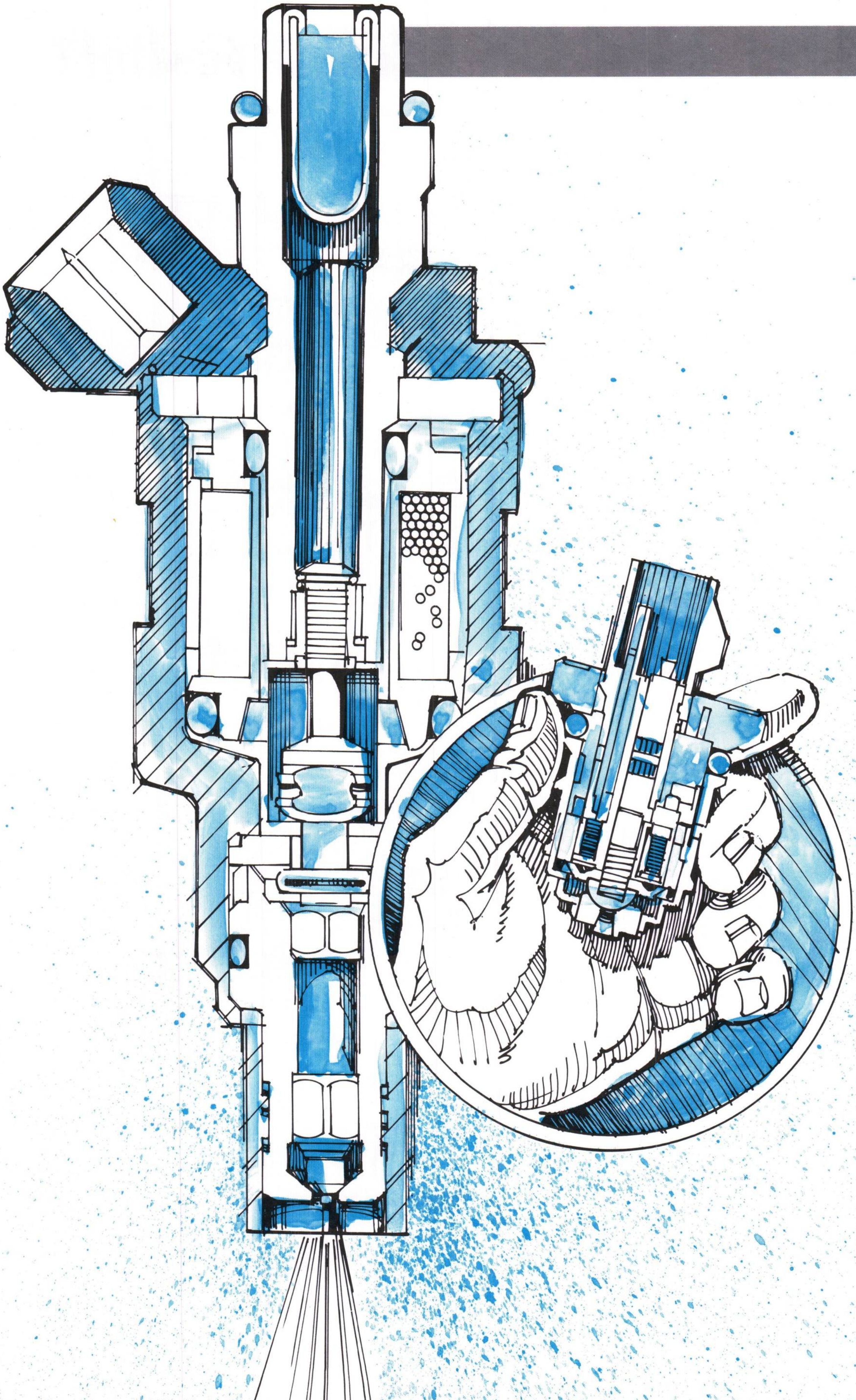


V6



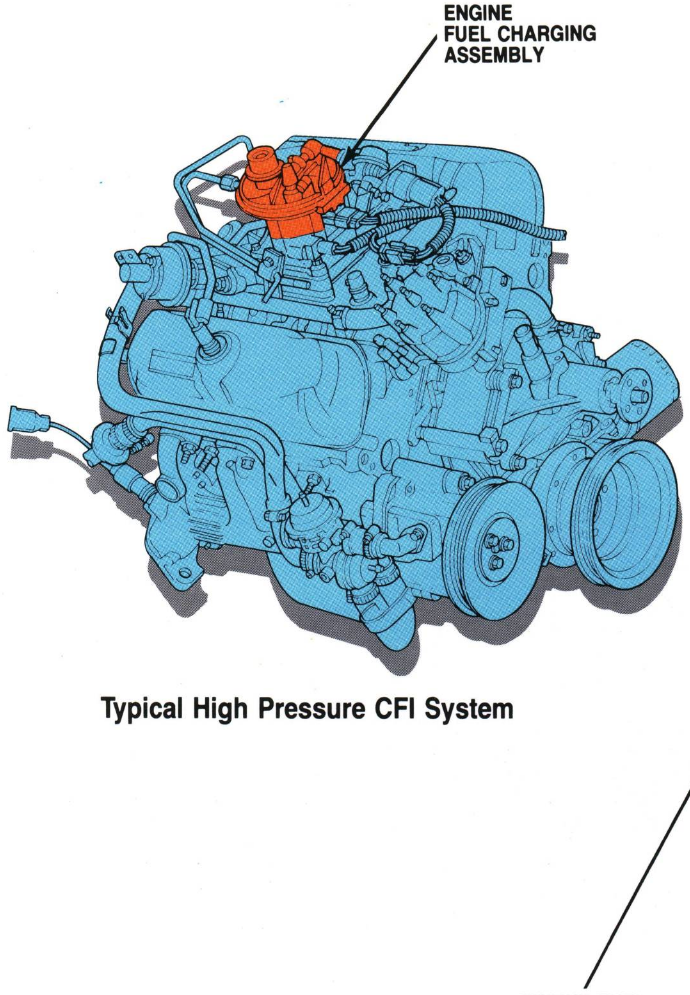
V8 (TRUCK – NON-AIR)

Locations of Pressure Regulators Typical Injection Supply Systems Showing

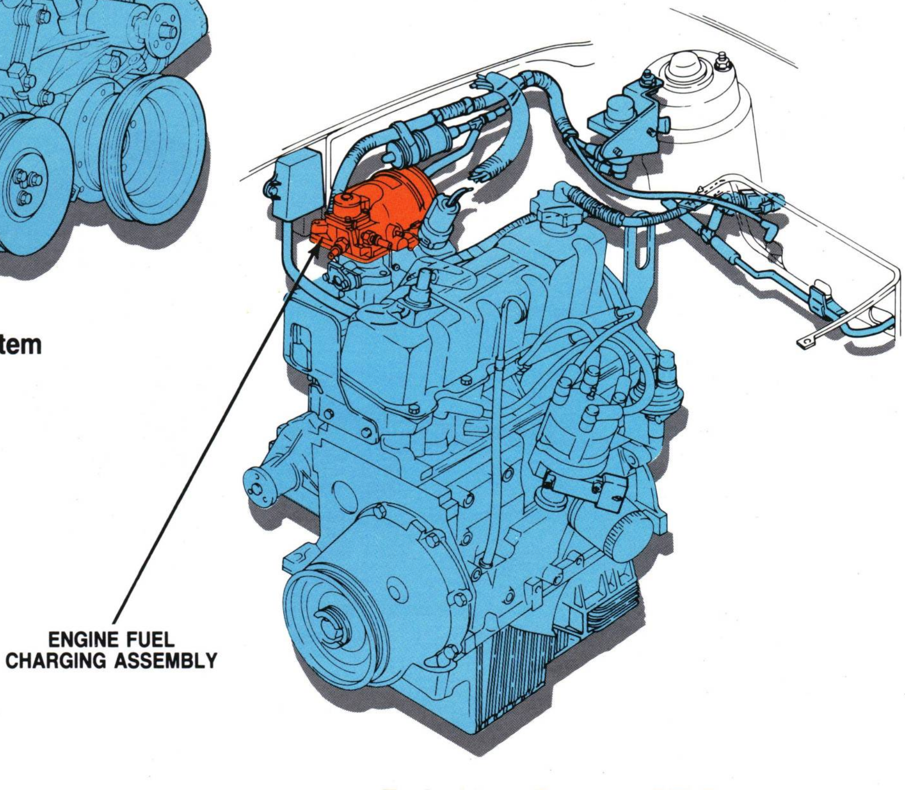


ELECTRONIC FUEL INJECTION SYSTEMS

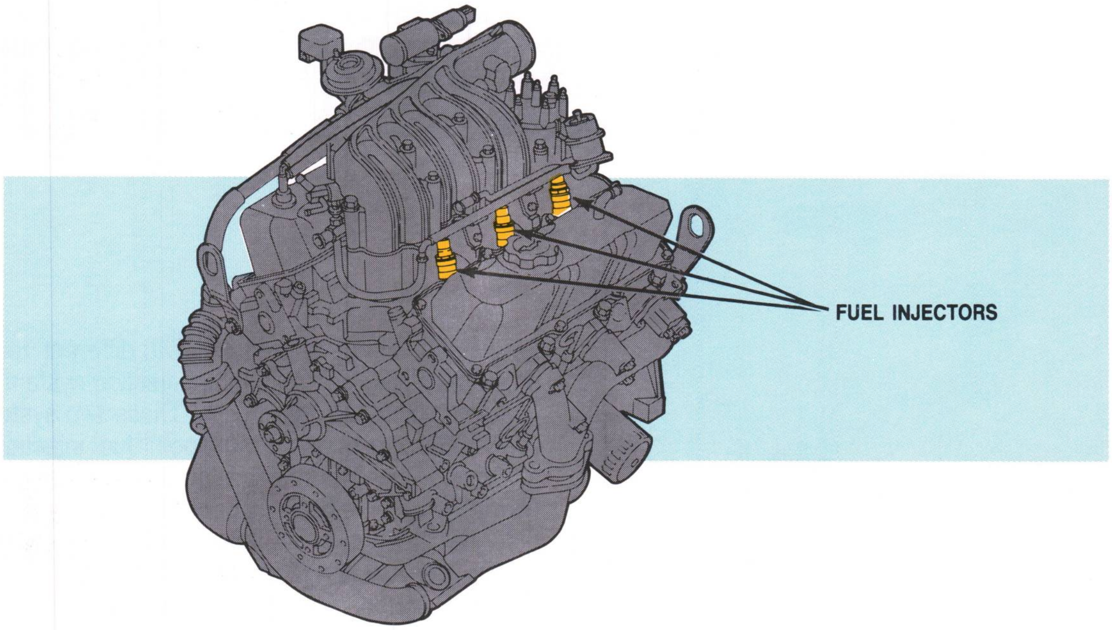
Ford Motor Company produces two different versions of an electronically controlled fuel injection system for use in automobiles and light trucks. These two systems are central fuel injection and multi-point fuel injection. These systems are similar in operation, in that they are both controlled by an electronic control assembly (ECA). The main difference is in the location of the injectors. In a central fuel injection (CFI) system, the fuel injector(s) is centrally located. Therefore, the name "central fuel injection" (CFI) is used to describe these systems.



Typical High Pressure CFI System

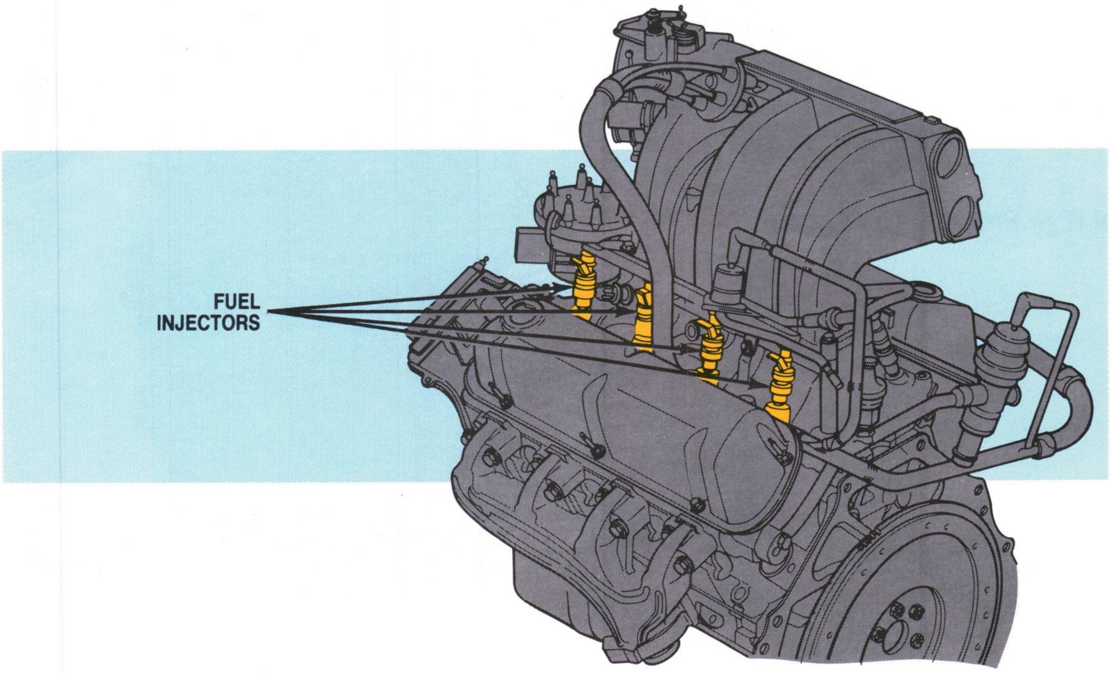


Typical Low Pressure CFI System

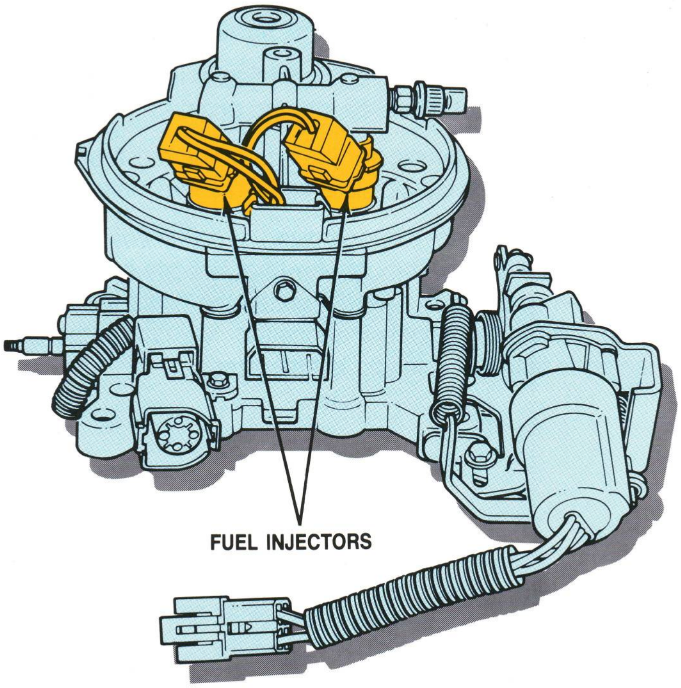


Six-Cylinder Multi-Point System

In a multi-point system, the fuel injectors are located in the lower intake manifold and positioned so that their tips are directing fuel in front of the intake valves. Therefore, the name "multi-point" is used to describe these systems. The multi-point system is also referred to as the "EFI" system.



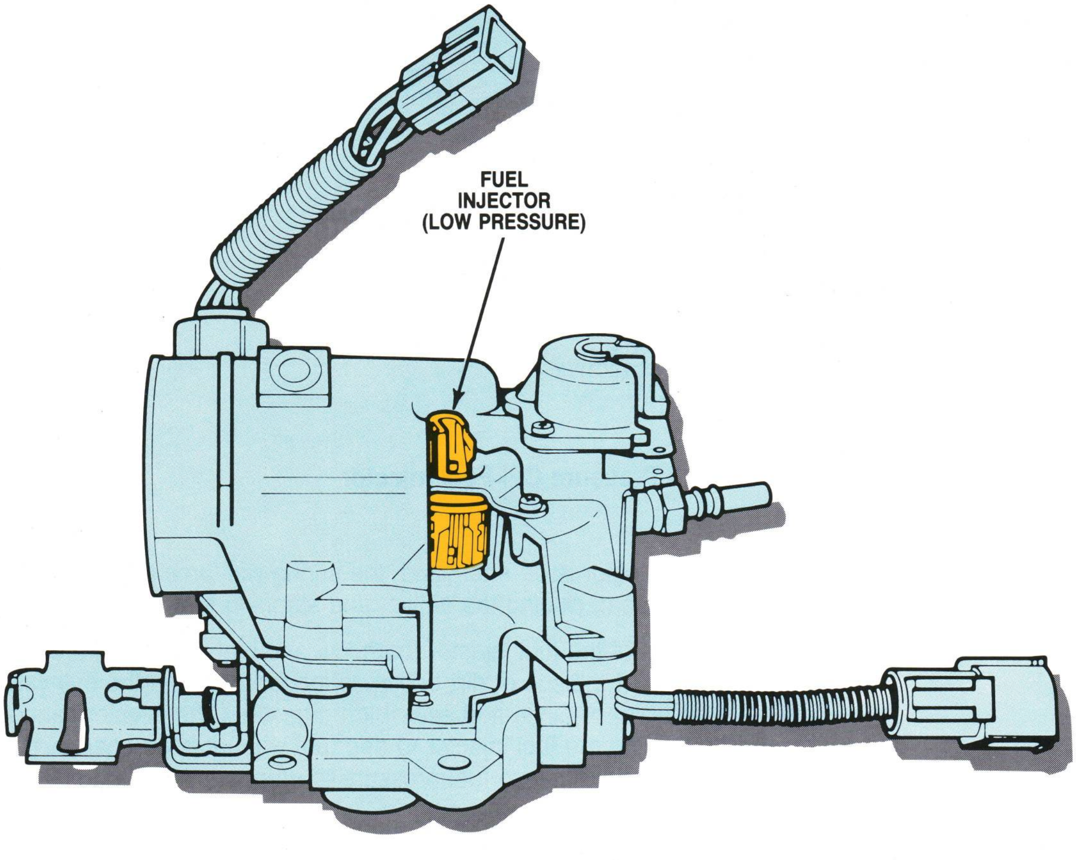
Eight-Cylinder Multi-Point System



High Pressure Engine Fuel Charging Assembly

CENTRAL FUEL INJECTION

The CFI systems are classified as single point, pulse time, modulated injection systems. Both high-pressure and low-pressure CFI systems are used. In the high-pressure system, fuel is metered by two fuel injectors mounted on an engine fuel charging assembly that resembles a carburetor. The low-pressure system uses one fuel injector mounted inside an engine fuel charging assembly.



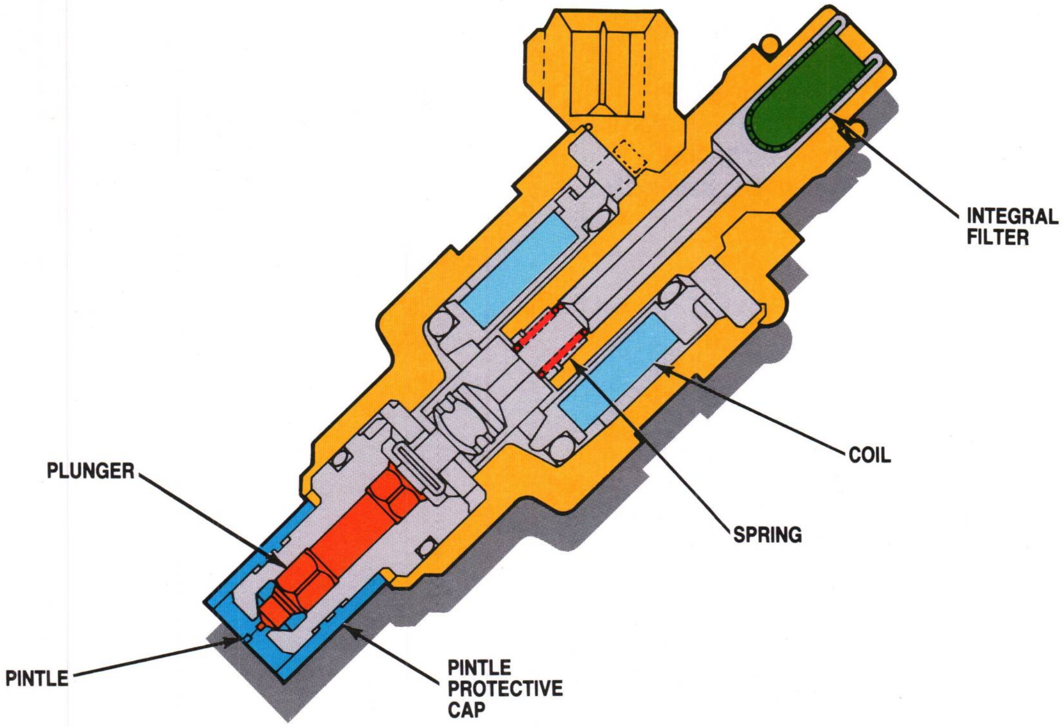
Low Pressure Engine Fuel Charging Assembly

High Pressure Electronic Fuel Injector

The high pressure electronic fuel injector is an electromechanical device that meters and atomizes fuel delivered into the engine.

Fuel enters the fuel injector through a fine mesh screen on top of the injector. It flows through the injector to a small reservoir located just above the pintle.

When the fuel injector is energized, a coil draws the plunger and pintle off their seat allowing fuel to flow through the throttle body and into the intake manifold. Fuel is atomized at the point where it enters the pintle area. Since the injector flow orifice is fixed and the fuel supply is regulated, fuel flow to the engine is controlled by the length of time the solenoid is energized.



High Pressure CFI Fuel Injector

When the fuel injector is de-energized, the spring will force the plunger and pintle down onto their seat, closing the orifice, and stopping fuel flow.

The components of the fuel injector (both low and high pressure) are machined to exact tolerances. If a piece of dirt becomes lodged between the ball valve and valve seat (low pressure) or pintle and seat (high pressure), the injector cannot close completely, causing the fuel injector to drip fuel when it is de-energized. A fuel injector stuck open will cause fuel pressure to drop, causing hard start-ups.

In turn, if a piece of dirt clogs one or more of the orifices in the low pressure fuel injector, fuel flow is reduced. In a high pressure injector, the spray pattern is affected.

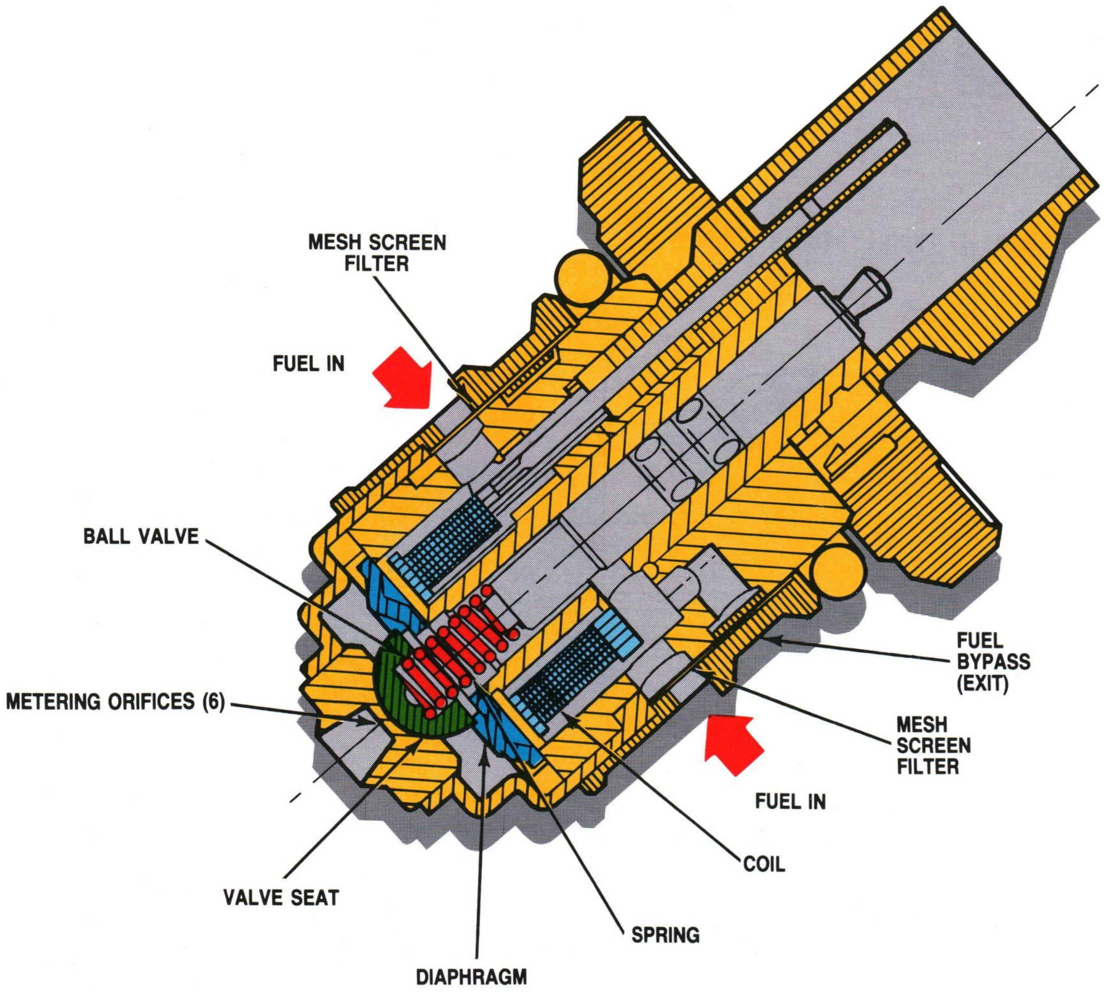
Low Pressure Electronic Fuel Injector

The low pressure electronic fuel injector is also an electromechanical device that meters and atomizes fuel delivered to the engine.

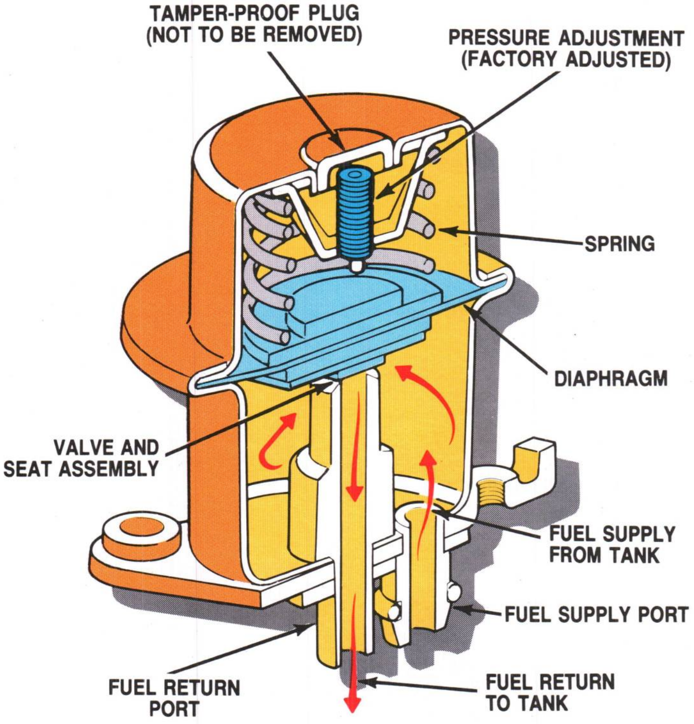
Fuel enters the fuel injector through a fine mesh screen filter and through four holes in the injector's side. Excess fuel exits through two holes located just above the entrance holes.

When the fuel injector is energized, a coil draws a metal diaphragm, which has a ball valve attached to the bottom of it, up against spring pressure. As the ball valve lifts off its seat, fuel flows through six metering orifices, through the throttle body and into the intake manifold. Since the orifices are fixed, and fuel pressure is regulated, fuel flow to the engine is controlled by the length of time the injector is energized (opened).

When the fuel injector is de-energized, the spring forces the diaphragm and ball valve back into the valve seat, stopping fuel flow.



LOW PRESSURE CFI FUEL INJECTOR



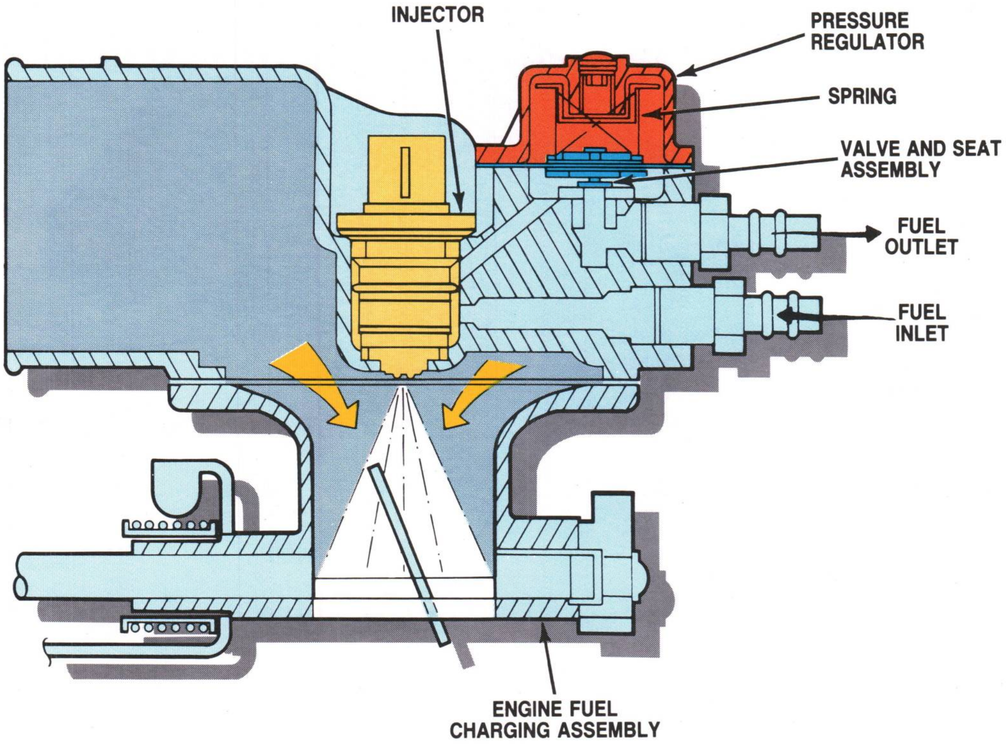
CFI Fuel Pressure Regulator — High Pressure System

Fuel Pressure Regulator

The fuel pressure regulator for both the high and low pressure CFI systems is a hydromechanical bypass device consisting of a metal housing with fuel supply and return ports.

In this metal housing, a spring-loaded diaphragm frees the valve and seat assembly to the return tube when the required fuel pressure setting is exceeded. This allows it to maintain a constant fuel pressure across the injectors.

The regulator not only regulates the fuel pressure, but it also traps fuel during engine shutdown, thus eliminating the possibility of vapor formation in the fuel line, and providing for instant restarts and initial idle speed. Fuel not required by the engine is returned to the fuel tank by way of a return line.



CFI Fuel Pressure Regulator — Low Pressure System

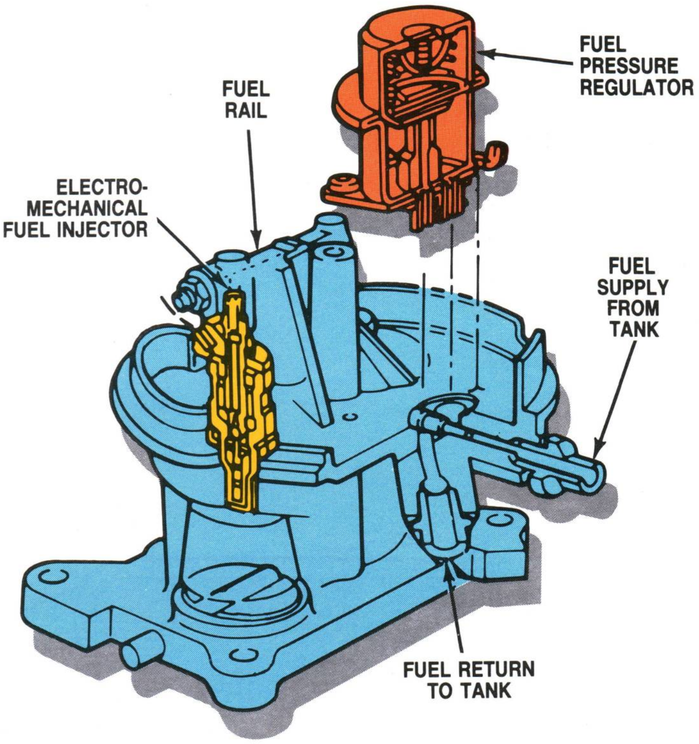
In the high pressure CFI system, the regulator is attached to the fuel charging assembly near the rear of the air horn surface. It regulates the fuel pressure to 39 psi.

In the low pressure CFI system, the regulator is an integral part of the fuel charging assembly. It regulates the pressure to 14.5 psi.

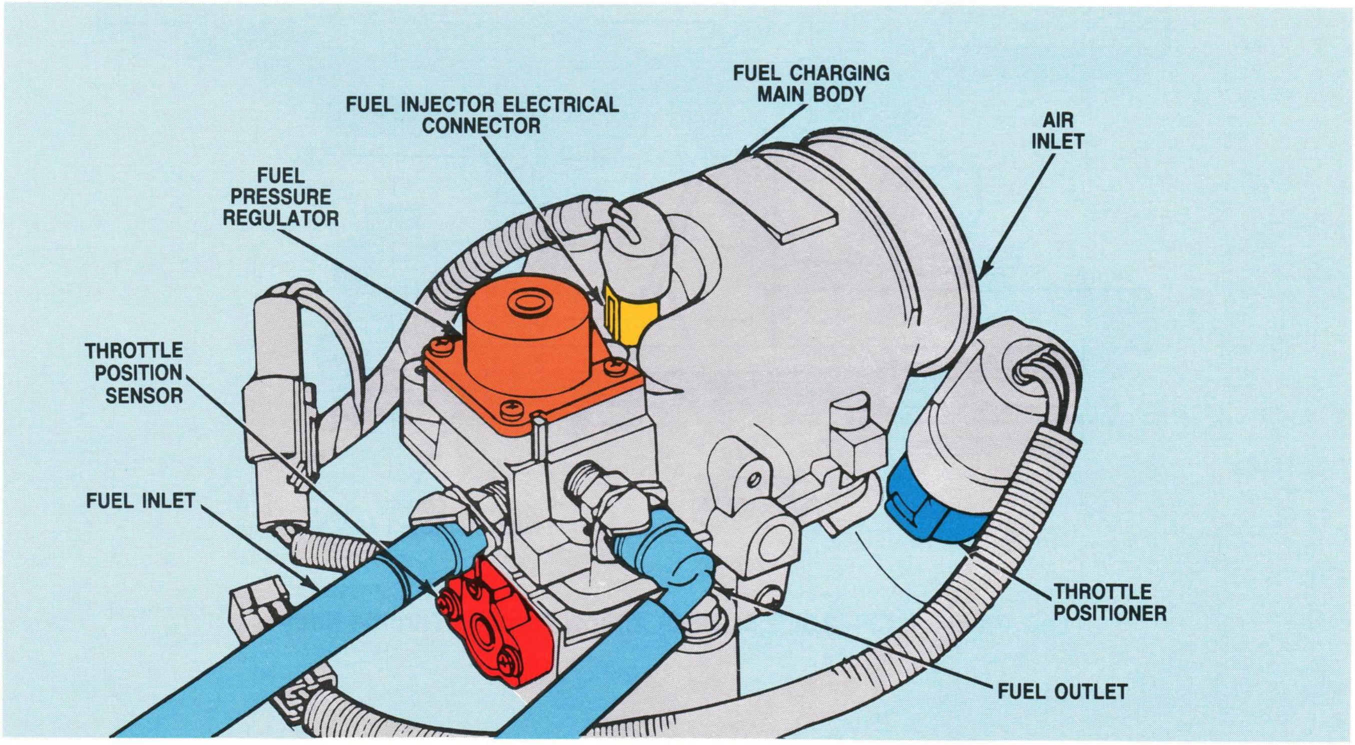
Air Intake

Air intake on an electronic fuel injected engine is very much the same as on carbureted engines.

In both CFI systems (low and high pressure), intake air to the engine is controlled by a butterfly valve or valves. The valve(s) is actuated by a linkage and pedal cable arrangement, operated by the driver, similar to the arrangement used on carburetors.



LOCATION OF FUEL PRESSURE REGULATOR IN HIGH PRESSURE SYSTEM

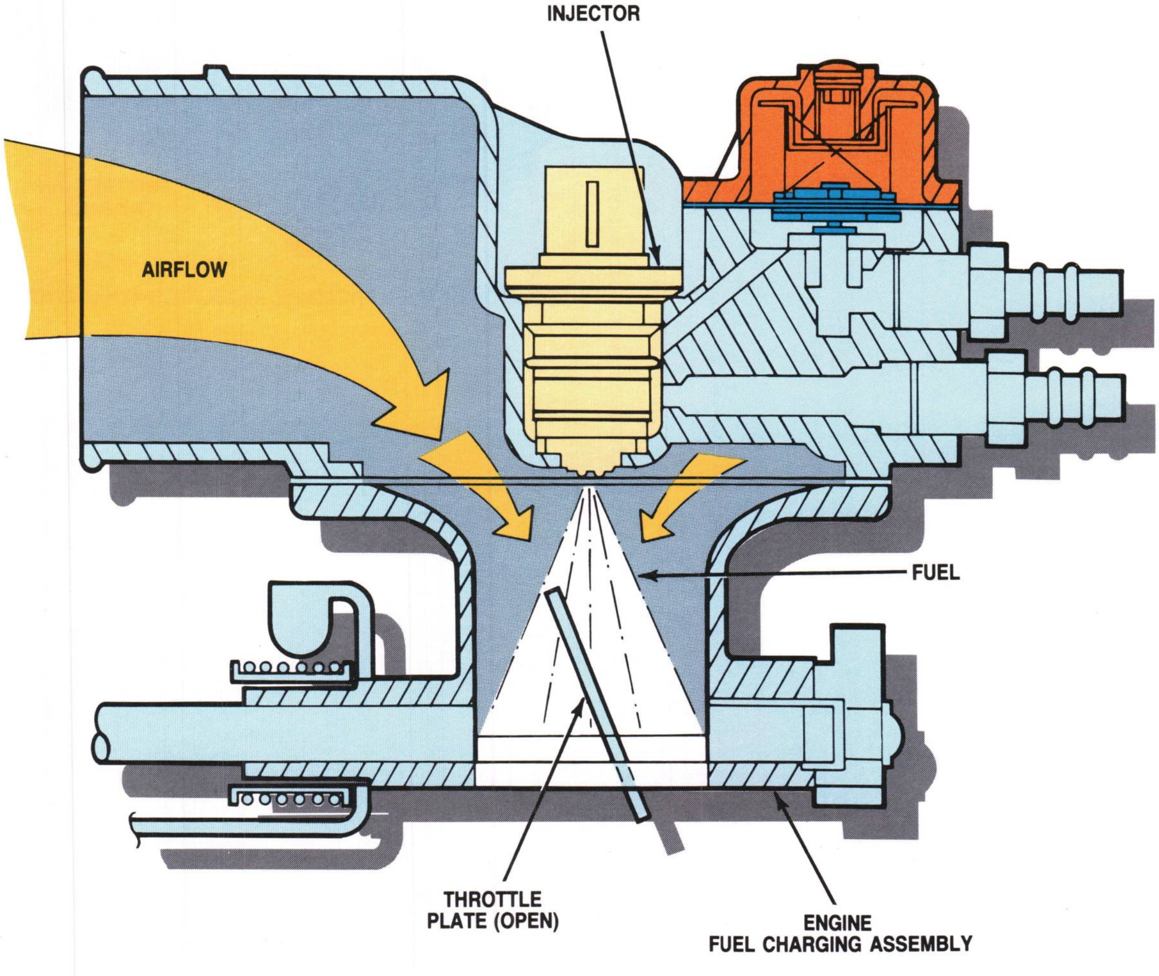


LOCATION OF FUEL PRESSURE REGULATOR IN LOW PRESSURE SYSTEM

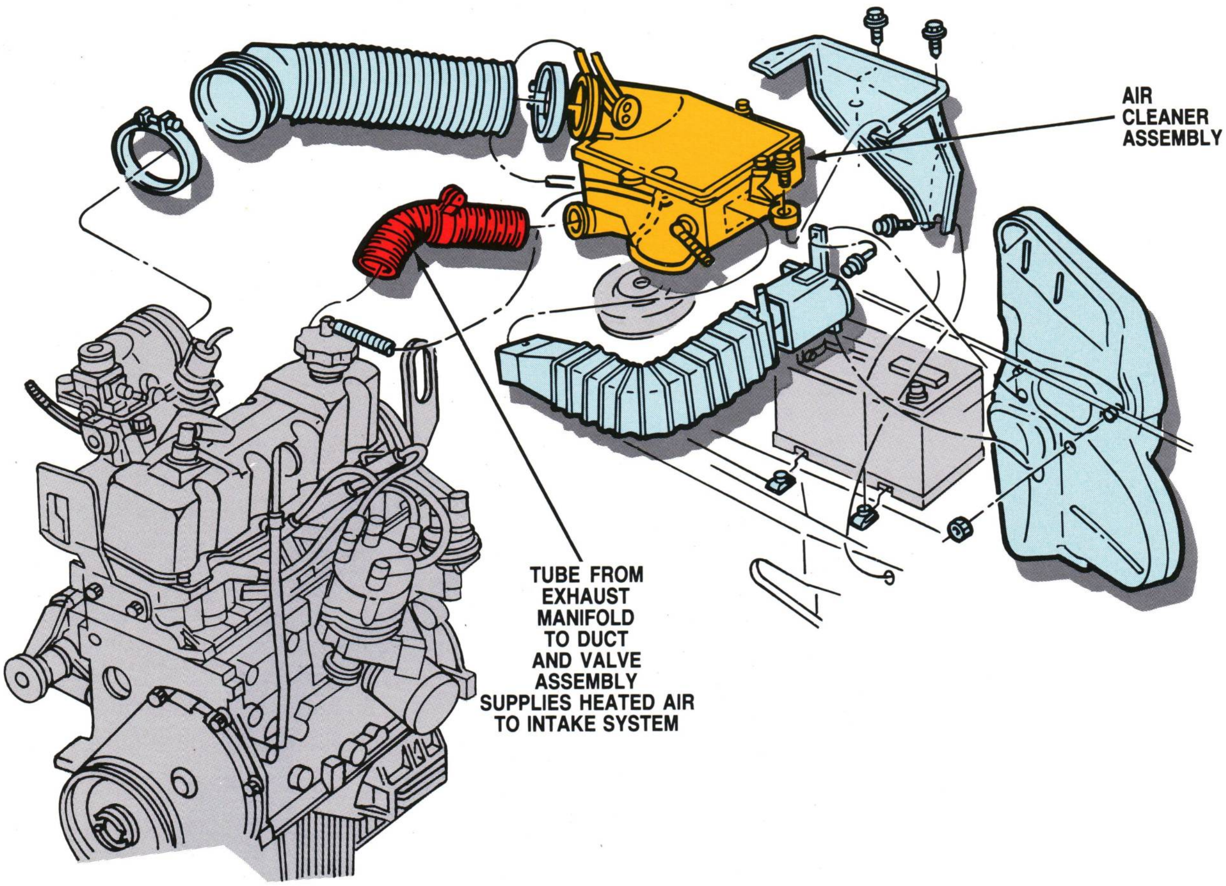
Low Pressure

Ford has two different low pressure systems. They operate in the same way. The differences between the two are in the location of the fuel injector in the throttle body, and in the design of the throttle body.

On the system used on the 2.3L and 2.5L HSC engines, the injector is mounted inside the throttle body. Airflow entering the engine comes in from the side and flows past the injector and down through the throttle body into the intake manifold.



Low Pressure CFI (2.3L/2.5L HSC) Airflow Through Throttle Body


AIR CLEANER ASSEMBLY
TUBE FROM EXHAUST MANIFOLD TO DUCT AND VALVE ASSEMBLY SUPPLIES HEATED AIR TO INTAKE SYSTEM

Air Intake System — 2.3L/2.5L HSC Low Pressure CFI System

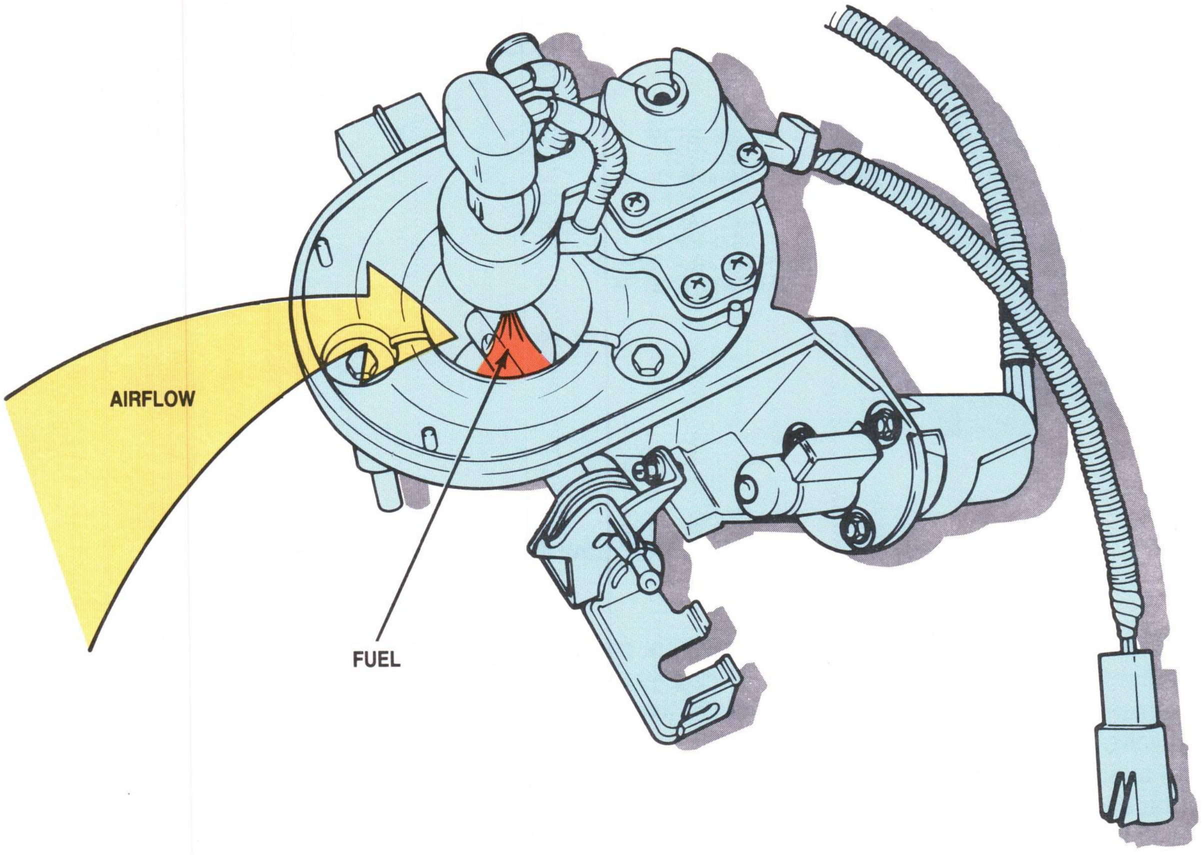
On this system the air cleaner assembly is mounted away from the throttle body. Air enters behind the front left fender, and flows into the air cleaner assembly, through the air cleaner element and a hose, and into the side of the throttle body. An air cleaner duct and valve assembly allows heated air (heated by a shroud on the exhaust manifold) to enter the engine during "cold engine" and cold climate operation. After the engine warms up, the duct and valve assembly closes, allowing non-heated air to enter the engine. This heated air helps the fuel to atomize better before entering the cylinders.

The duct and valve assembly is controlled by vacuum through a bimetal sensor. During cold operation the bimetal opens, allowing vacuum to open the duct and valve assembly. As the engine warms up, the bimetal bleeds off vacuum, closing the duct and valve assembly.

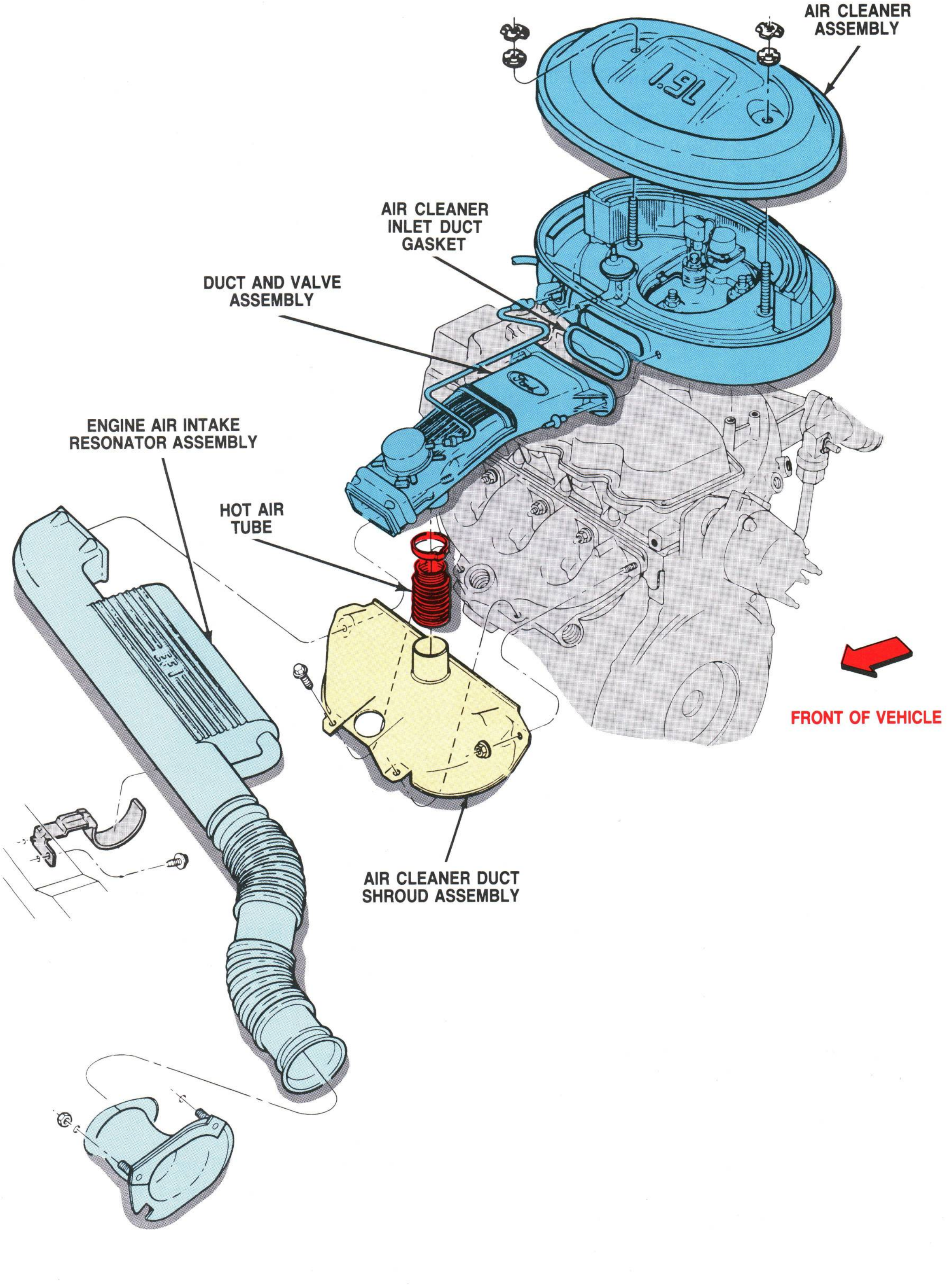
On the system for the 1.9L engine, the injector is mounted above the opening to the throttle body. This set-up looks similar to that of a single venturi carburetor. Airflow enters the throttle body from the top and mixes with the fuel as it passes the fuel injector.

On this system the air cleaner assembly is mounted directly on top of the throttle body, as in a carbureted system.

This system also uses a duct and valve assembly. Its operation is the same as that described for the 2.3L and 2.5L HSC engines.



Low Pressure CFI (1.9L) Airflow Through Throttle Body


AIR CLEANER ASSEMBLY
1.9L
AIR CLEANER INLET DUCT GASKET
DUCT AND VALVE ASSEMBLY
ENGINE AIR INTAKE RESONATOR ASSEMBLY
HOT AIR TUBE
FRONT OF VEHICLE
AIR CLEANER DUCT SHROUD ASSEMBLY

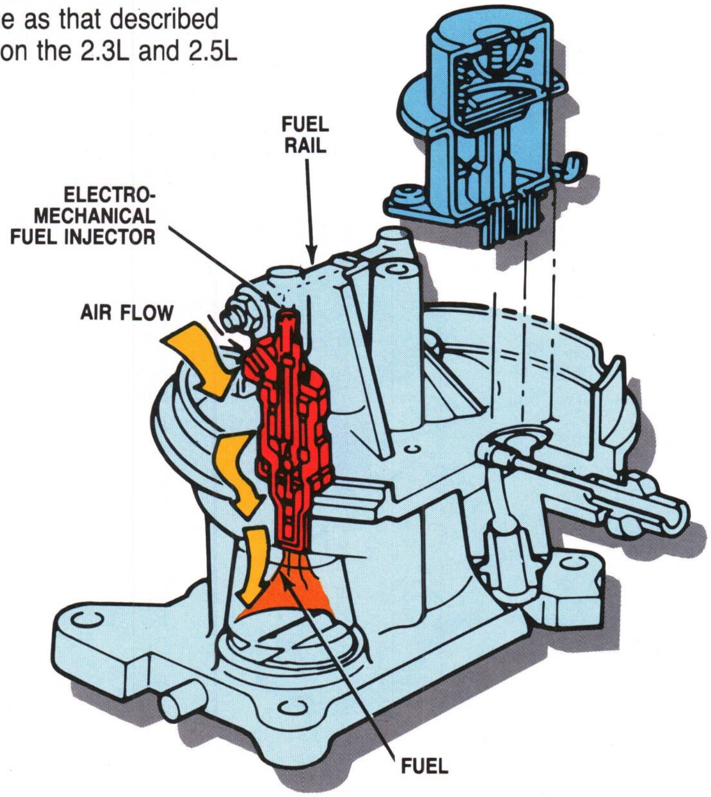
Air Intake System — 1.9L Low Pressure CFI System

High Pressure

On the high pressure CFI system, two injectors are mounted in the throttle body: one in each air passage through the throttle body. Airflow enters the throttle body from the top and mixes with the fuel as it passes the fuel injectors.

On this system the air cleaner is also mounted directly on top of the throttle body, as in a carbureted system.

The high pressure system also uses a duct and valve assembly. Its operation is the same as that described for the low pressure system used on the 2.3L and 2.5L HSC engines.



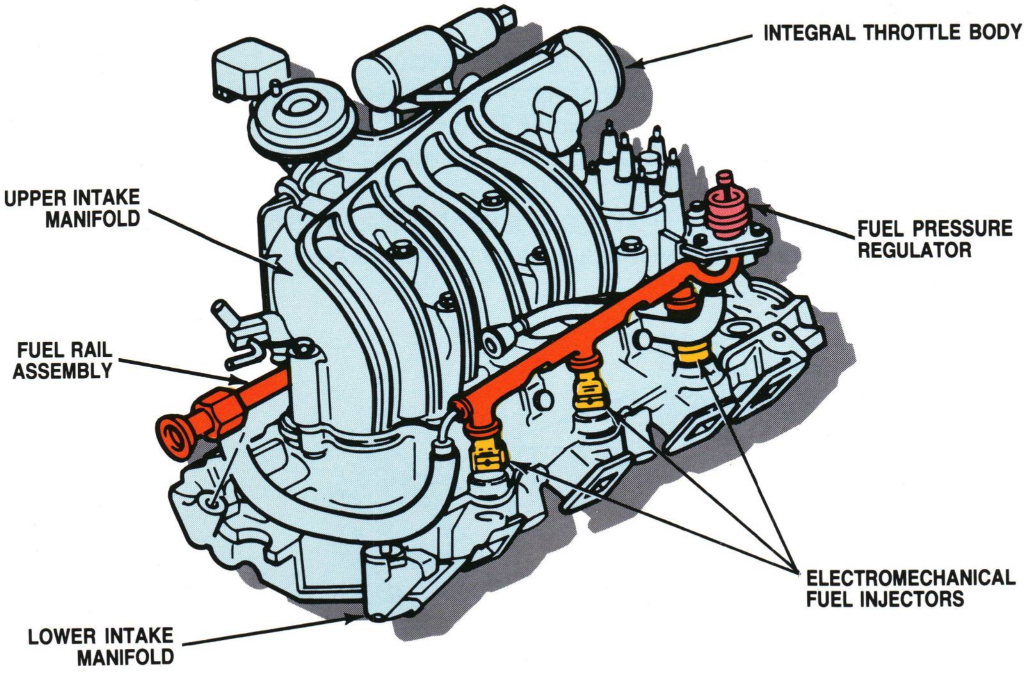
High Pressure CFI Airflow Through Throttle Body

MULTI-POINT FUEL INJECTION (EFI)

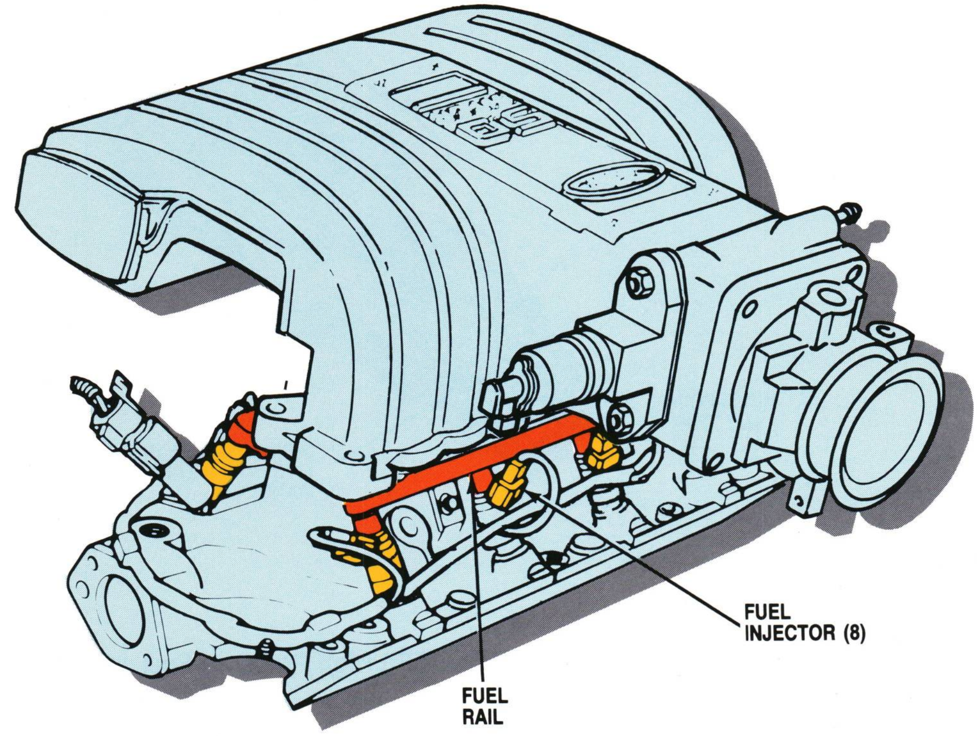
The multi-point (EFI) systems are classified as multi-point, pulse time, mass airflow, or adaptive speed/density air measurement systems. The injectors are mounted in the lower intake manifold. This manifold is part of an assembly comprised of a throttle body, upper intake manifold assembly, lower intake manifold assembly and the fuel rail assembly. The fuel injectors and the fuel pressure regulator are attached to the fuel rail.

The injectors in multi-point (EFI) fuel injection systems fire in three different ways:

- Simultaneously.
- Four at one time; two in each bank on the 5.0L EFI truck applications. Cylinders 1, 4, 6 and 7 fire as one set, while cylinders 2, 3, 5 and 8 fire as another set.
- Sequentially (on 5.0L SEFI passenger car applications). In this system each injector is fired as the intake valve opens for that cylinder.



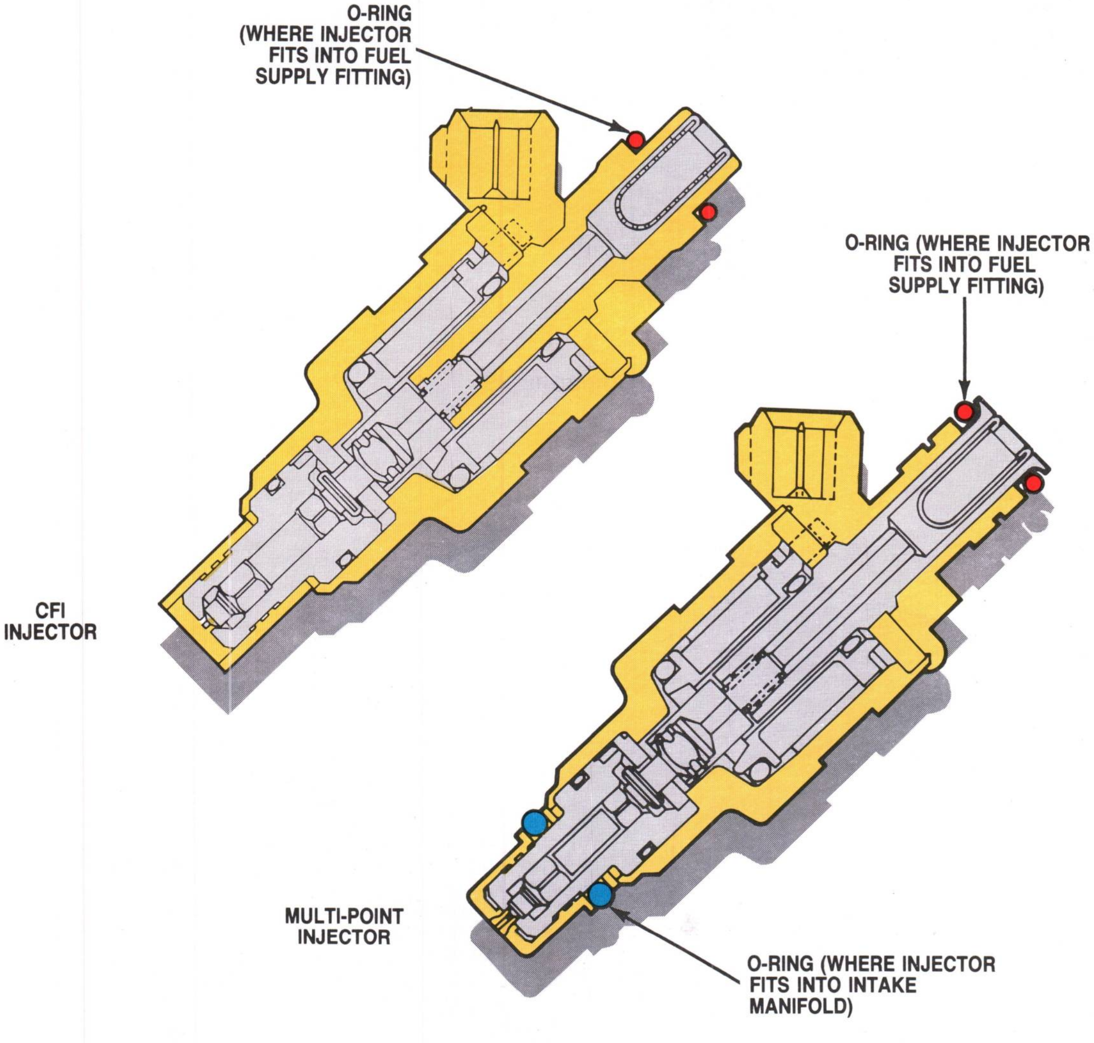
EFI Components



SEFI Engine

High Pressure Electronic Fuel Injector

All multi-point (EFI) systems use high pressure electronic fuel injectors. The operation of these injectors is identical to that of the high pressure injectors used on the CFI system. The difference between the multi-point (EFI) and CFI injectors is in the housing and the number and location of O-rings. The CFI injector has only one O-ring, located where the injector fits into the fuel supply fitting on the throttle body. The multi-point (EFI) injector has two O-rings, one where the injector fits into the fuel supply fitting on the fuel rail, and one where the injector fits into the intake manifold.

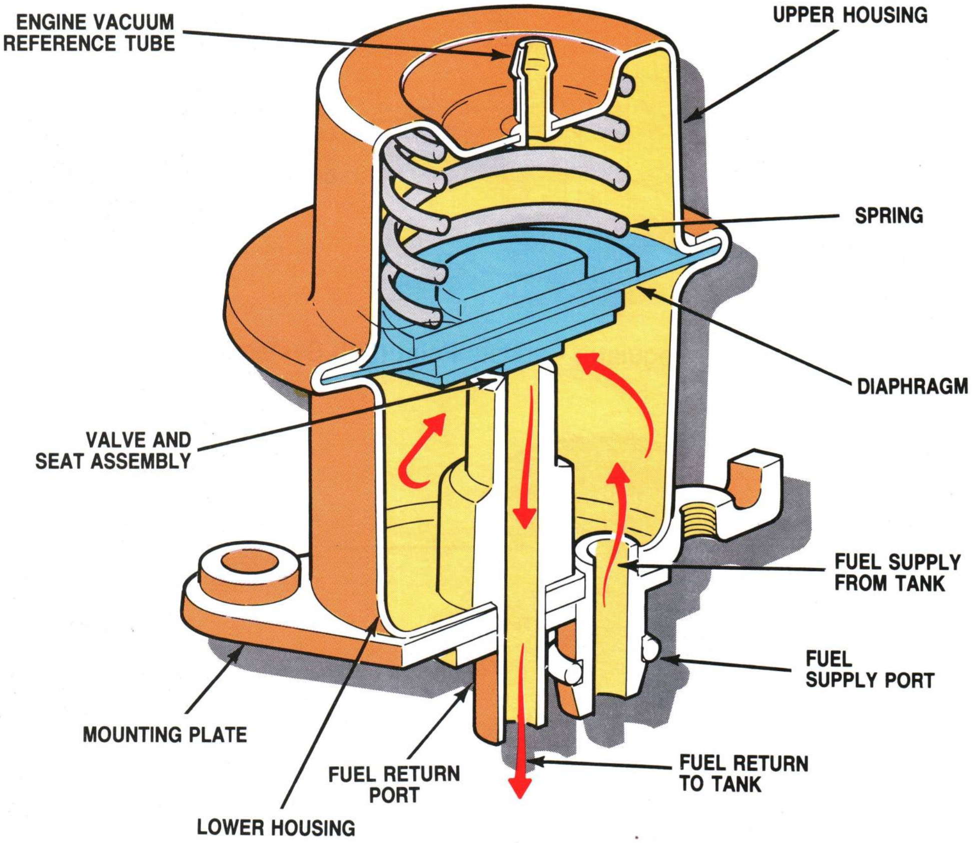

O-RING (WHERE INJECTOR FITS INTO FUEL SUPPLY FITTING)
O-RING (WHERE INJECTOR FITS INTO FUEL SUPPLY FITTING)
CFI INJECTOR
MULTI-POINT INJECTOR
O-RING (WHERE INJECTOR FITS INTO INTAKE MANIFOLD)

Differences Between CFI and Multi-Point (EFI) High Pressure Fuel Injectors

Fuel Pressure Regulator

The fuel pressure regulator for the multi-point system is also a hydromechanical bypass device which consists of a metal housing with fuel supply and return ports. The major difference between this regulator and the one used on the CFI systems is that this regulator is also controlled by intake manifold vacuum and/or pressure.

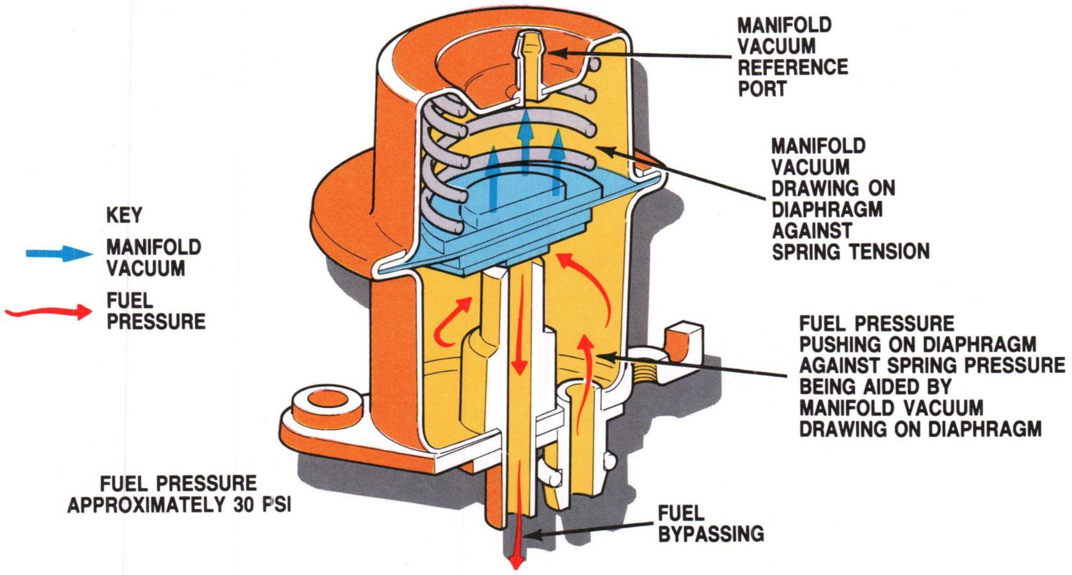
An intake manifold reference port has been added to the metal housing cover in place of the adjustment screw used on the CFI regulator. This intake manifold reference port, which is located on the dry side of the regulator, allows fuel pressure to be modulated by intake manifold vacuum (or pressure) as well as by fuel pressure.



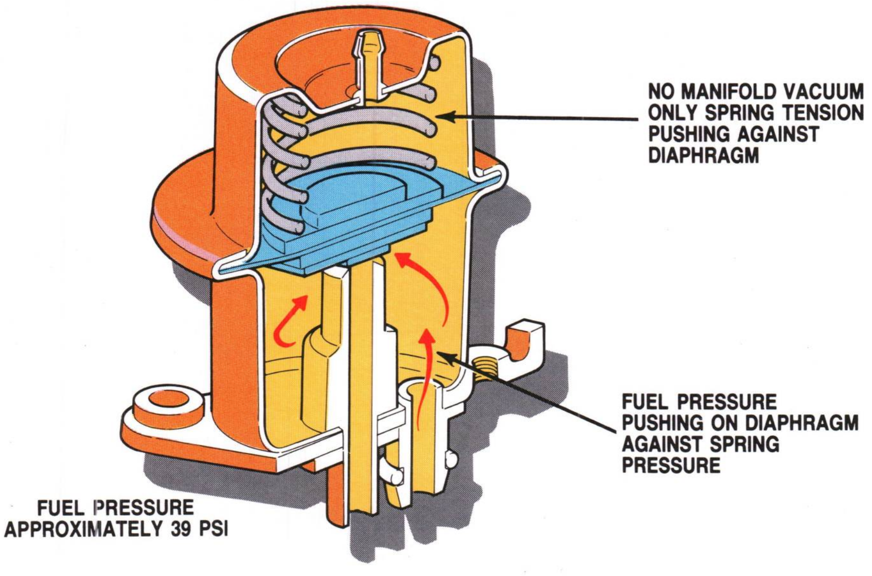
Fuel Pressure Regulator — Multi-Point (EFI) System

Fuel pressure against the spring-loaded diaphragm frees the valve and seat assembly to the return tube, with the aid of intake manifold vacuum — which is also trying to move the valve and seat off the return tube. During conditions of high vacuum (such as idle or closed throttle deceleration), the vacuum signal is high, and vacuum is drawing on the diaphragm. This vacuum, along with the fuel pressure on the opposite side of the diaphragm, moves the seat and valve assembly off the return tube, allowing fuel to return to the fuel tank, and reducing pressure to the injectors to as low as 30 psi.

During times of low vacuum (such as wide-open throttle), there is little or no vacuum to the regulator, and the fuel pressure itself "pushes" on the diaphragm, raising the valve and seat assembly off the return tube. Since only fuel pressure is acting on the diaphragm, a smaller amount of fuel returns, causing the pressure to the injectors to increase to approximately 39 psi. This action allows fuel pressure to be referenced to intake manifold vacuum (or pressure). This permits fuel pressure to remain relatively constant across the injectors, with respect to manifold vacuum (or pressure).

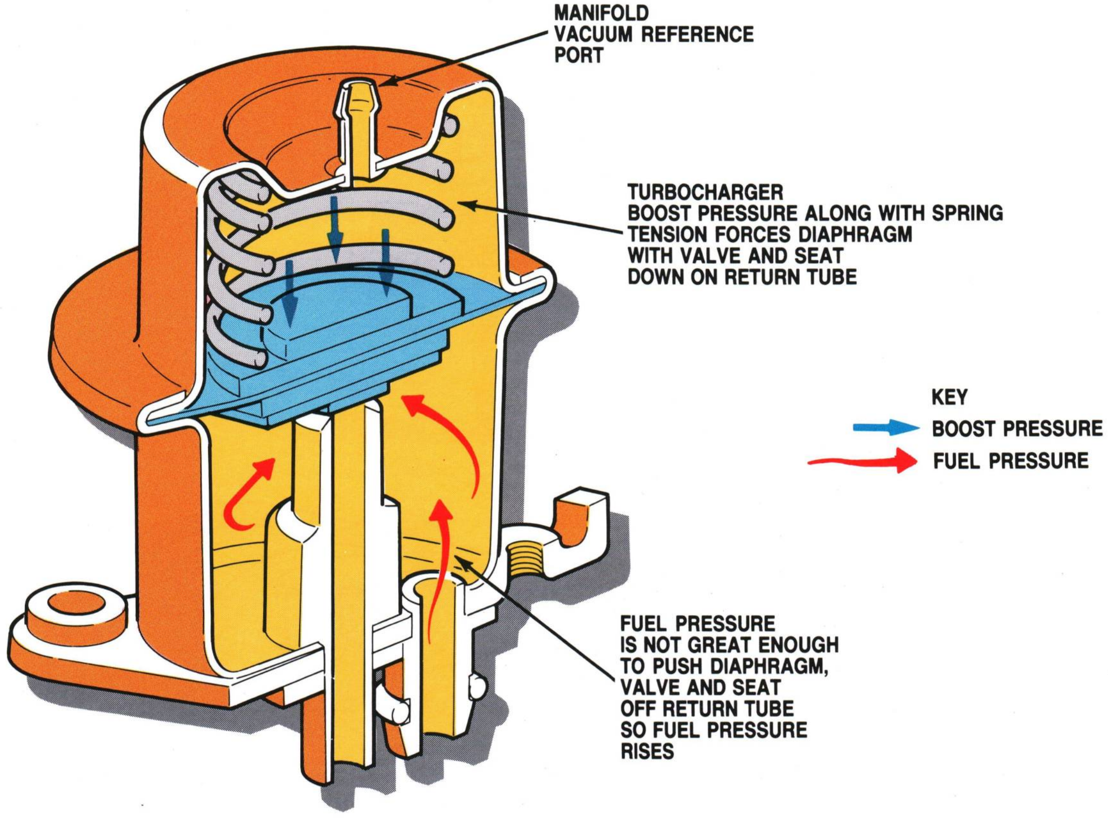

MANIFOLD VACUUM REFERENCE PORT
MANIFOLD VACUUM DRAWING ON DIAPHRAGM AGAINST SPRING TENSION
KEY
MANIFOLD VACUUM
FUEL PRESSURE
FUEL PRESSURE PUSHING ON DIAPHRAGM AGAINST SPRING PRESSURE BEING AIDED BY MANIFOLD VACUUM DRAWING ON DIAPHRAGM
FUEL PRESSURE APPROXIMATELY 30 PSI
FUEL BYPASSING

Fuel Pressure Regulator — Multi-Point (EFI) System — 30 PSI


NO MANIFOLD VACUUM ONLY SPRING TENSION PUSHING AGAINST DIAPHRAGM
FUEL PRESSURE PUSHING ON DIAPHRAGM AGAINST SPRING PRESSURE
FUEL PRESSURE APPROXIMATELY 39 PSI

Fuel Pressure Regulator — Multi-Point (EFI) System — 39 PSI

In a turbocharged engine, when a boost condition is encountered (such as wide-open throttle), pressure in the intake manifold pushes against the diaphragm, preventing the valve and seat assembly from lifting from the return tube. This causes greater fuel pressure, which is required under a boost condition. During a 10-pound boost condition, the fuel pressure reading will be approximately 45-50 psi.

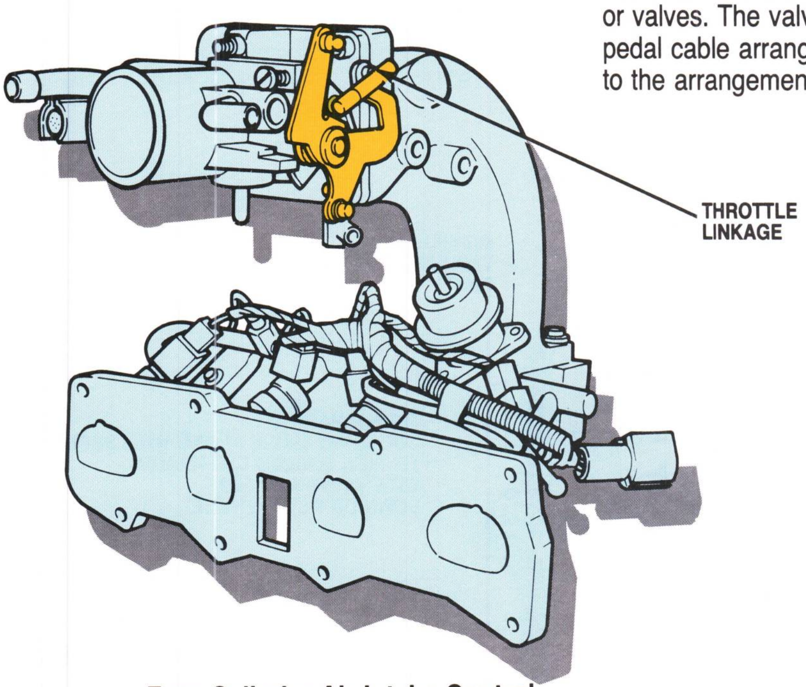

MANIFOLD VACUUM REFERENCE PORT
TURBOCHARGER BOOST PRESSURE ALONG WITH SPRING TENSION FORCES DIAPHRAGM WITH VALVE AND SEAT DOWN ON RETURN TUBE
KEY
BOOST PRESSURE
FUEL PRESSURE
FUEL PRESSURE IS NOT GREAT ENOUGH TO PUSH DIAPHRAGM, VALVE AND SEAT OFF RETURN TUBE SO FUEL PRESSURE RISES

FUEL PRESSURE APPROXIMATELY 45-50 PSI
DUE TO TURBOCHARGER BOOST PRESSURE

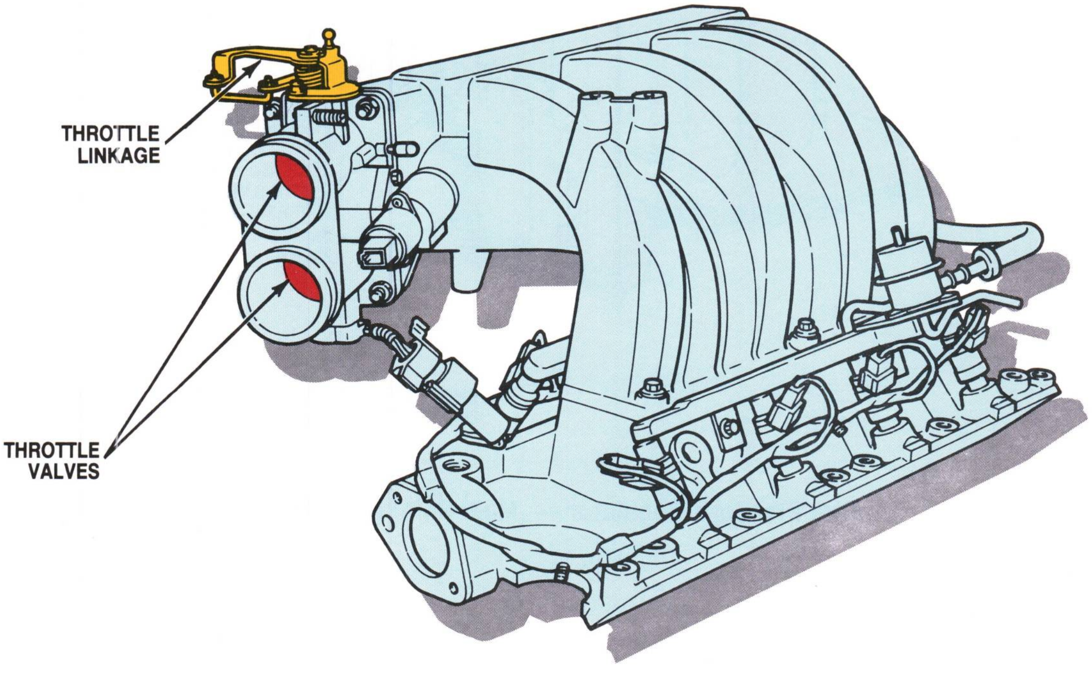
Fuel Pressure Regulator — Multi-Point (EFI) System — 45-50 PSI

Air Intake

Air intake on the multi-point (EFI) fuel injected engine is very much the same as that on some CFI systems. The intake air to the engine is controlled by a butterfly valve or valves. The valve(s) is actuated by a linkage and pedal cable arrangement operated by the driver, similar to the arrangement used on the CFI systems.



Four-Cylinder Air Intake Control

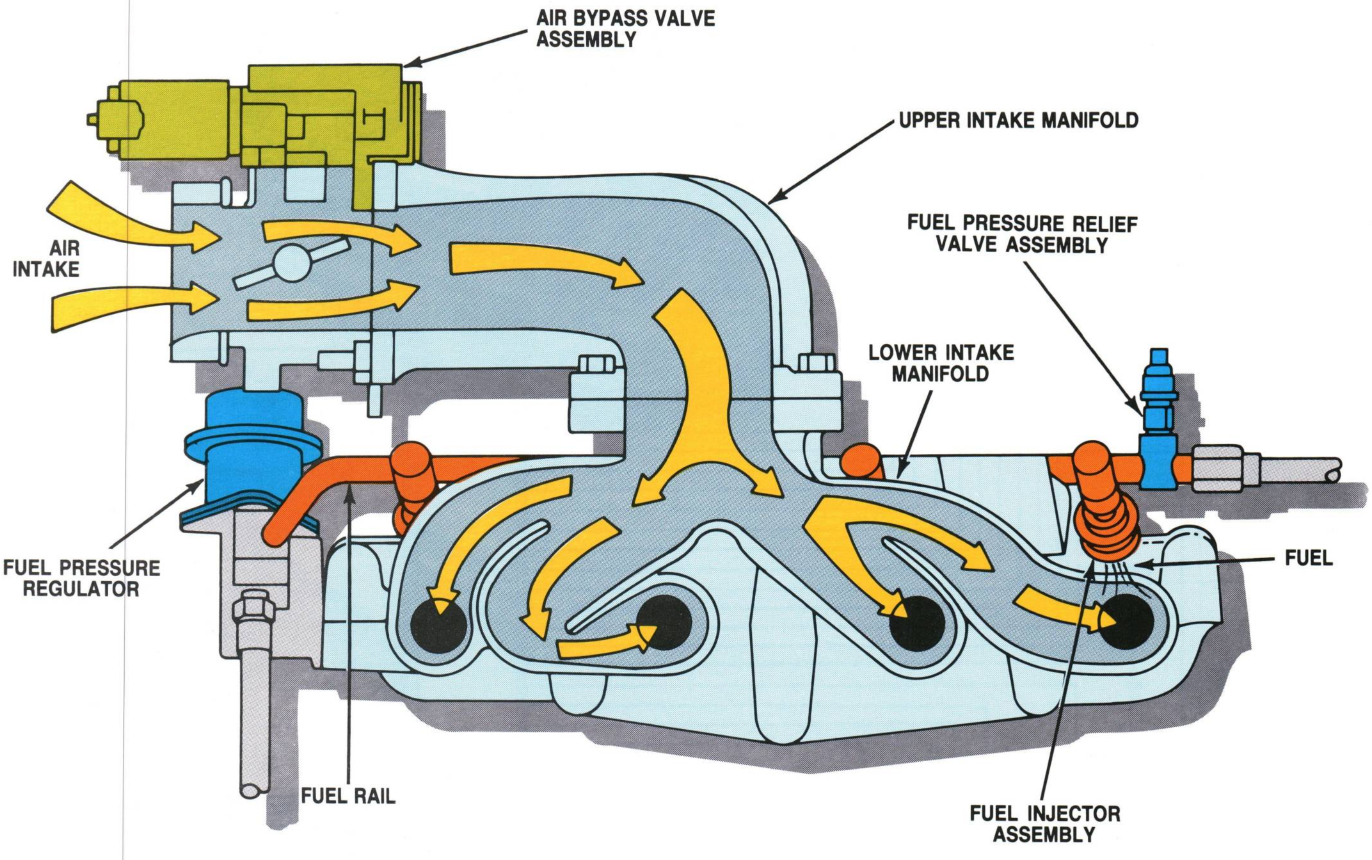


Eight-Cylinder Air Intake Control

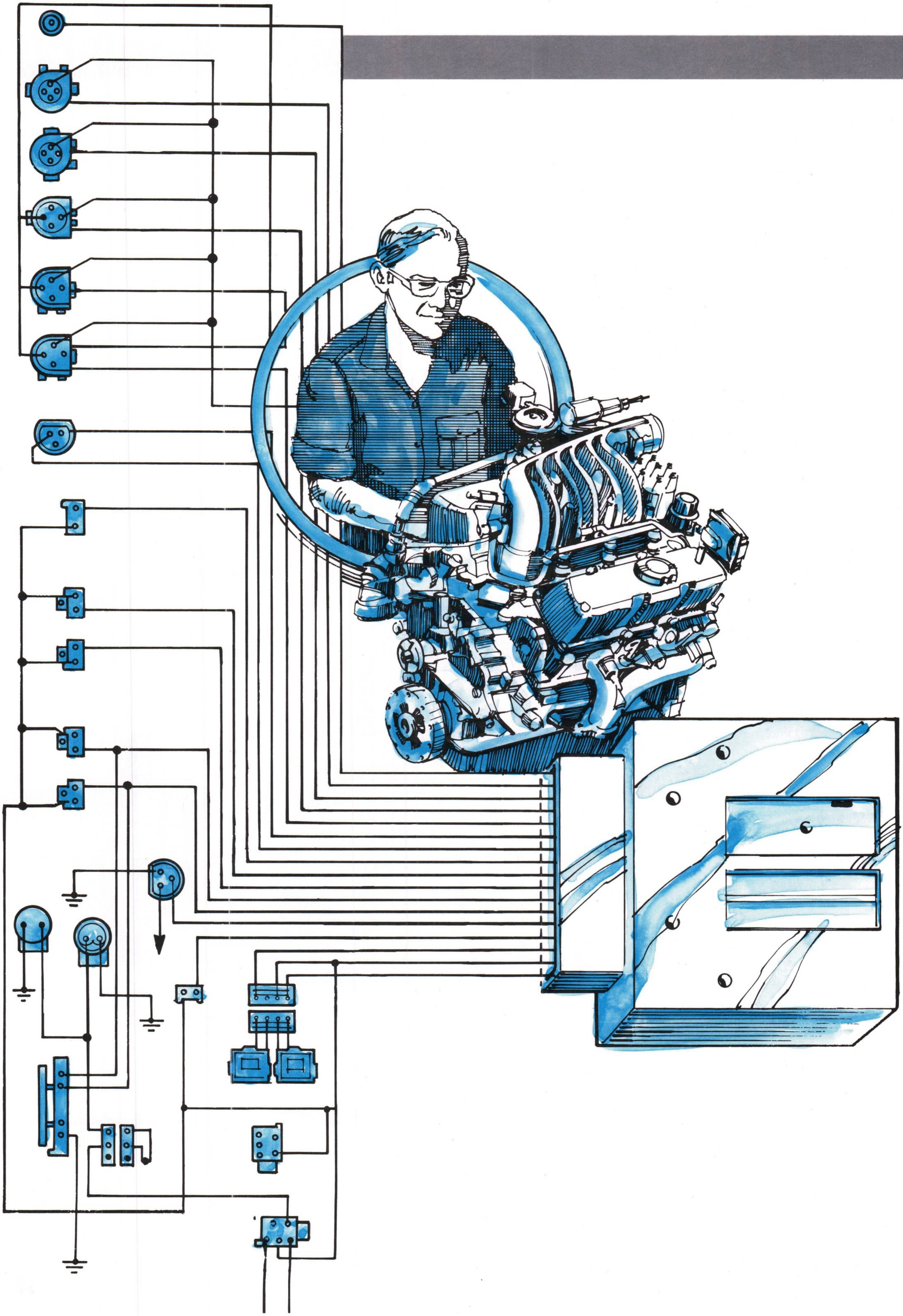
Airflow enters the throttle body, flows into the upper intake manifold and then into the lower intake manifold where it swirls around the fuel injector and mixes with the fuel. It then enters the cylinder as an air/fuel mixture.

The air cleaner assembly is mounted away from the throttle body. Air enters the air cleaner assembly and flows through a hose into the throttle body.

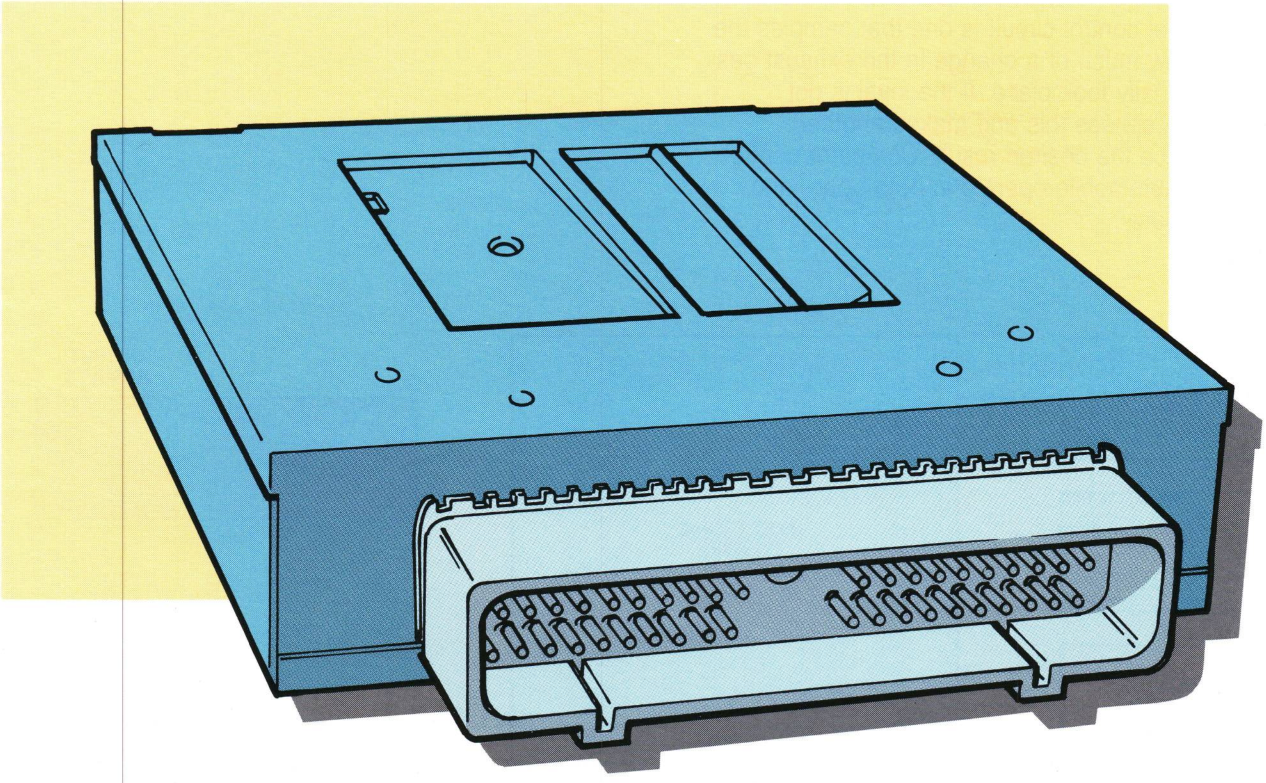
A duct and valve assembly is used on certain engine calibrations to help prevent the air filter element from icing up during cold weather operating conditions. This system operates in the same manner as the duct and valve assemblies used on CFI systems.



Air Intake Through Throttle Body and Upper and Lower Intake Manifolds — Multi-Point (EFI) System



ELECTRONIC ENGINE CONTROL OPERATION



Electronic Control Assembly (ECA)

ELECTRONIC CONTROL ASSEMBLY

The fuel injection system is controlled electronically by a small microprocessor called an electronic control assembly (ECA).

This unit receives input signals from a series of sensors. The ECA makes computations based on these inputs, and then sends controlling outputs to the fuel injectors in order to achieve the desired air/fuel ratio.

The ECA sends out a reference voltage to potentiometers and other sensors that operate as voltage dividers. These sensors require a constant source of reference voltage to provide an accurate signal. The ECA monitors the return voltage from these sensors. This information provides the ECA with engine operating conditions.

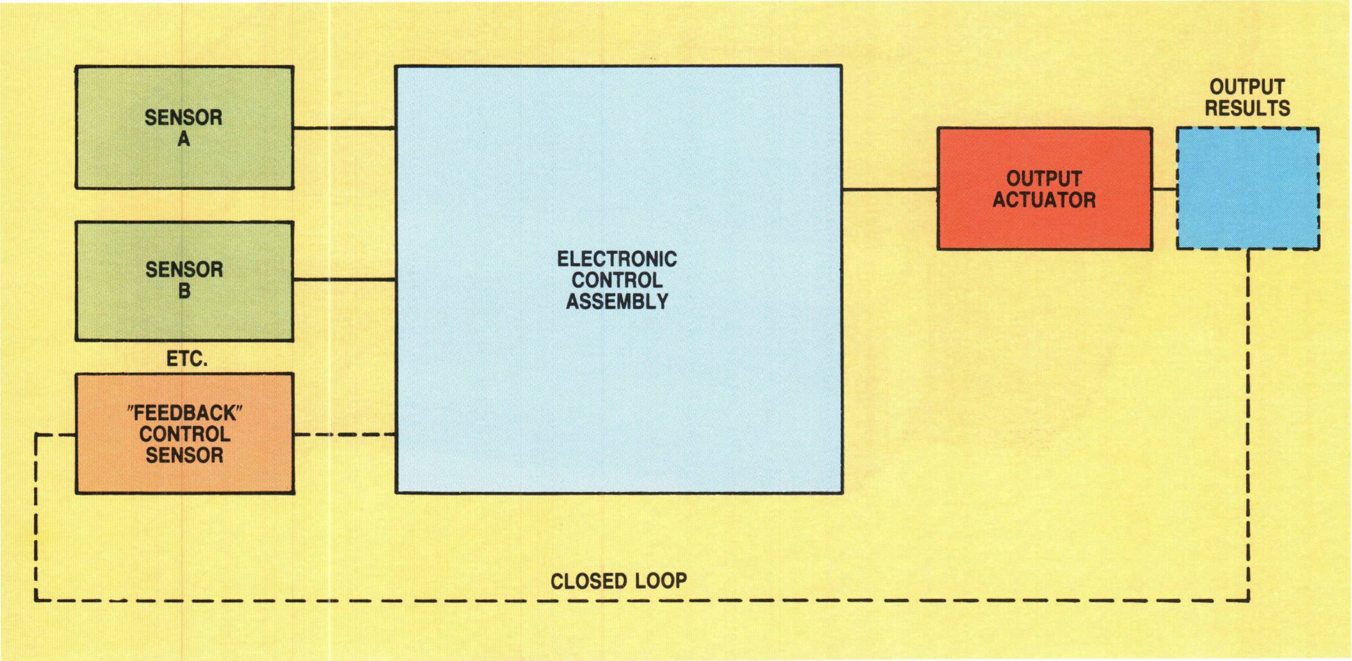
The reference voltage, abbreviated VREF, is regulated in, and supplied from, the ECA. It is rated at 5 volts.

OPERATING MODES

The ECA operates in two modes: open-loop control and closed-loop control.

In open-loop control operation, the ECA ignores exhaust gas oxygen level when making a change in engine operation. Open-loop control is used in situations where fuel enrichment is needed to provide acceptable engine operation during such conditions as "cold engine" or wide-open throttle.

A closed-loop fuel control circuit is one that samples the output to see how much of a change in the exhaust gas oxygen level actually took place. If the level is not correct, the ECA senses this and makes another change to produce the desired result. Computer control systems in the automobile operate in both open- and closed-loop modes.



Closed-Loop Fuel Control

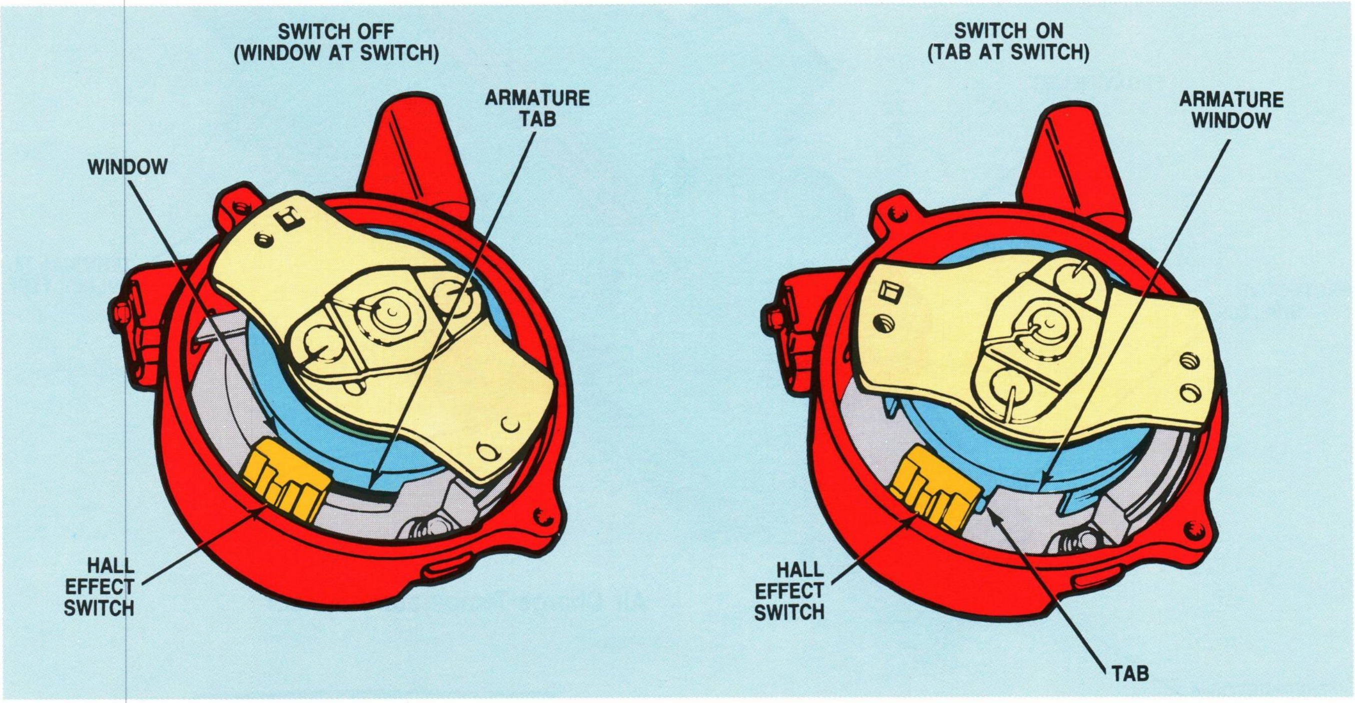
The Exhaust Gas Oxygen (EGO) sensor is used to sense the exhaust gas oxygen level. In cold engine operation, when the EGO sensor is not yet in operation, the ECA operates in open-loop mode because it has no way to determine what the air/fuel ratio is. Once the sensor warms up and starts to signal the ECA with air/fuel ratio information, and when other system operating conditions such as warm engine coolant are met, the ECA begins making changes to the air/fuel ratio according to the EGO sensor signals.

ECA INPUTS — FUEL CONTROL

In order for the ECA to calculate when to energize the injectors and what the injector pulse width should be, it must receive updated information relating to the engine operating conditions. These conditions include:

- Crankshaft position and engine RPM.
- Intake air temperature and/or intake airflow.
- Engine coolant temperature.
- Exhaust gas oxygen content.
- EGR flow rate.
- Throttle position.
- Manifold absolute pressure and/or barometric absolute pressure.

The following information describes these conditions and the sensors which are used to monitor them for the ECA. Not all of these sensors are used on all fuel injection systems.



Profile Ignition Pickup Sensor

Crankshaft Position and Engine RPM

The ECA needs to know crankshaft position and engine speed to determine when to energize the injectors. This information is supplied to the ECA by a profile ignition pickup (PIP) sensor.

The PIP sensor, which is located inside the universal distributor, consists of a Hall effect device on one side, and a magnet on the other. A rotary cup with windows and tabs rotates, passing through the space between the Hall effect device and the magnet. When a window is between the Hall effect device and the magnet, the magnetic flux path from the magnet is not completed. In this case, the switch is off and the Hall effect device sends no signal.

When a tab passes between the device and the magnet, the magnetic lines of flux increase. The flux lines are shunted through the tab back to the magnet, increasing the effect of the magnet on the Hall effect device and turning the device on.

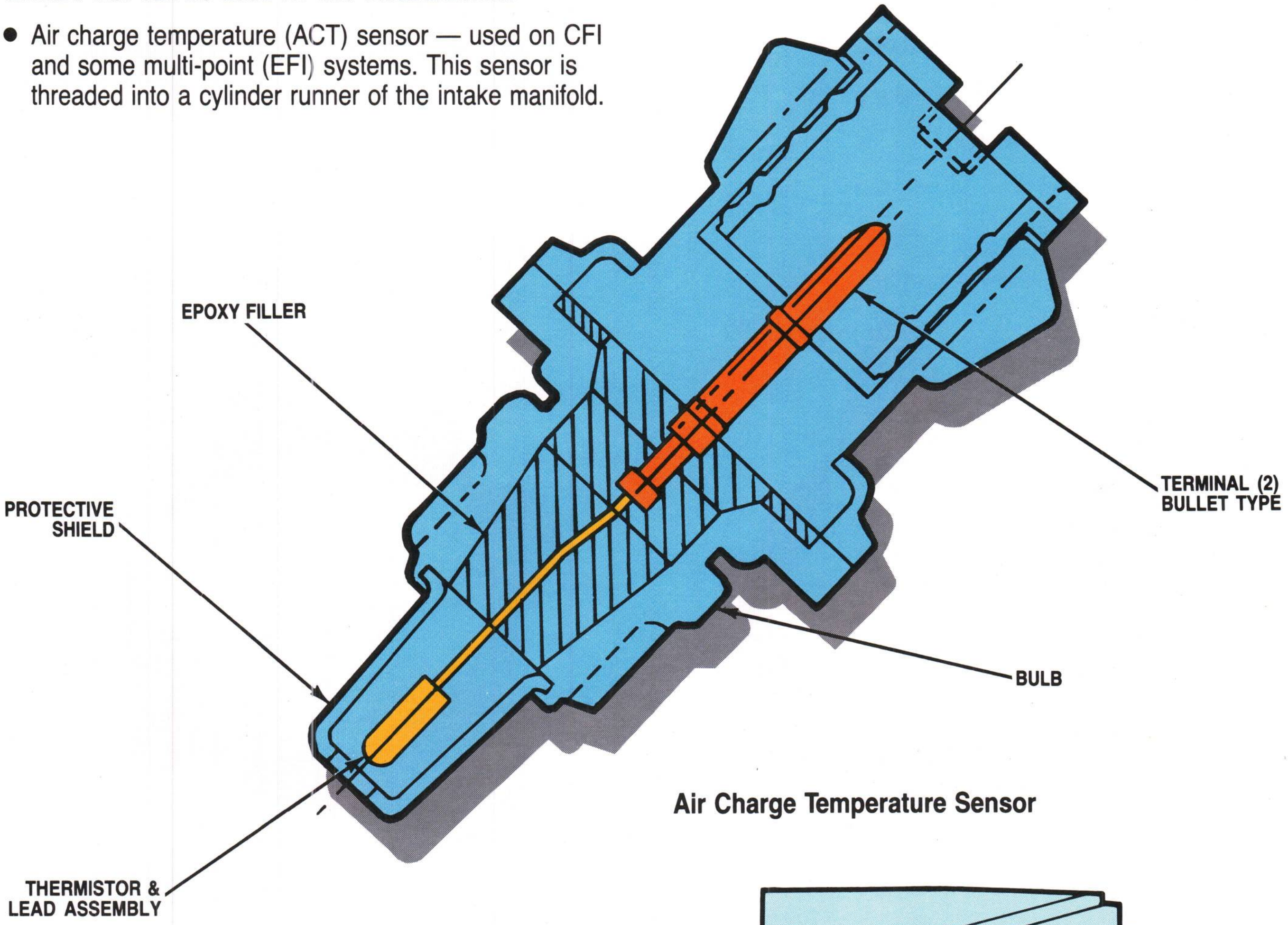
When the next window passes between the device and the magnet, the device is again shut down and the signal is turned off.

These voltage pulses are used by the ECA for sensing crankshaft position and engine speed to compute the desired time and pulse width to energize the injector.

Intake Air Temperature

Intake air temperature is required for use as a density corrector for fuel flow calculation, and for proportioning the cold enrichment fuel flow. There are two types of sensors that can be used for this measurement:

- Air charge temperature (ACT) sensor — used on CFI and some multi-point (EFI) systems. This sensor is threaded into a cylinder runner of the intake manifold.

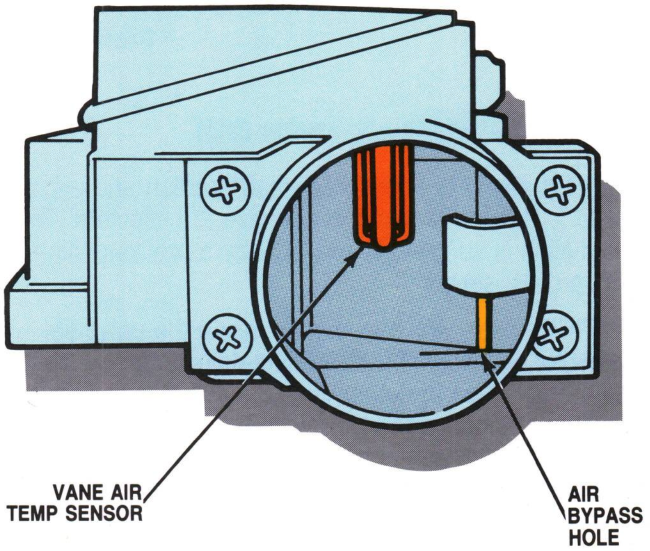


Air Charge Temperature Sensor

- Vane air temperature (VAT) sensor — used on multi-point (EFI) systems only. The VAT sensor is an integral part of the vane meter.

Both the ACT and VAT sensors are thermistor sensors which change their resistance as the temperature changes. The greater the temperature, the lower the resistance.

The ECA applies a reference voltage to these sensors, and monitors the resultant output voltage produced by the sensors as their resistance changes due to temperature changes. The output signal will vary depending on air charge temperature. The greater the temperature, the higher the output signal will be to the ECA.

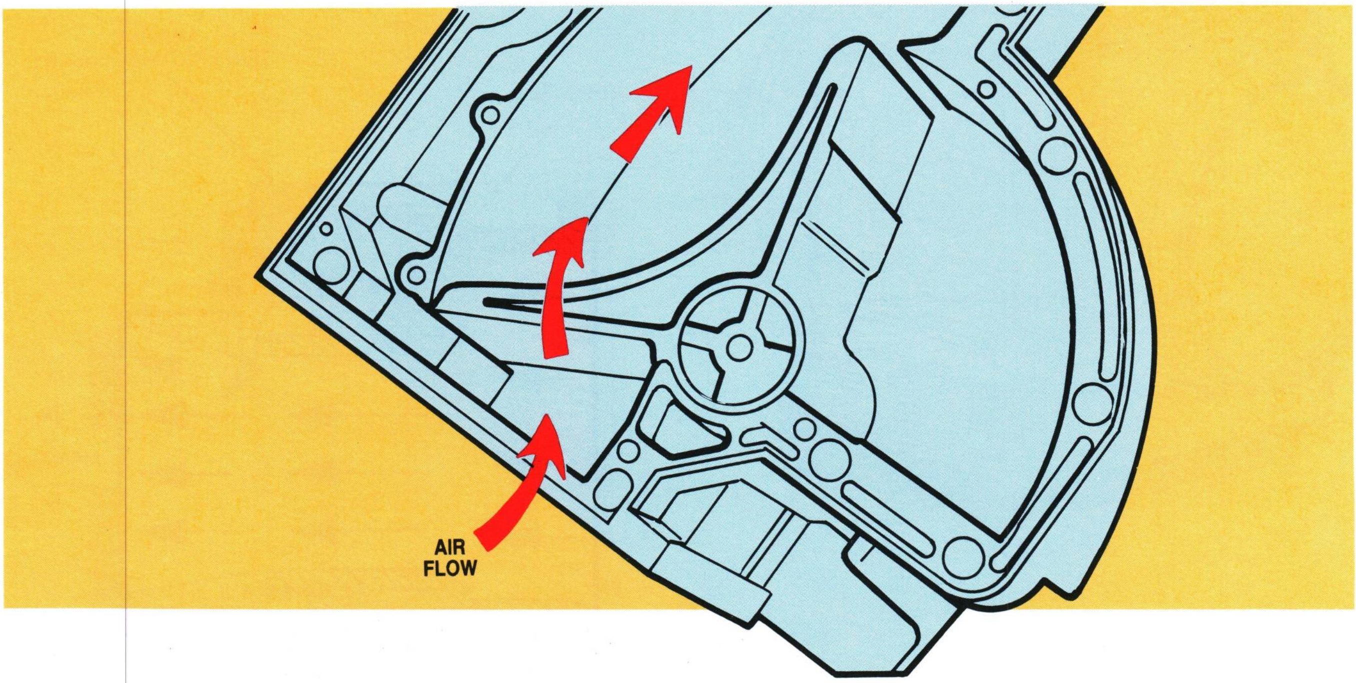


Vane Meter

Intake Airflow

On mass airflow-type systems, a sensor must be used to measure the intake airflow. One of two types of sensors may be used, depending on system application:

- Vane meter (contains vane airflow and vane air temperature sensors)
- Mass airflow sensor (contains a hot wire)



Vane Airflow Sensor

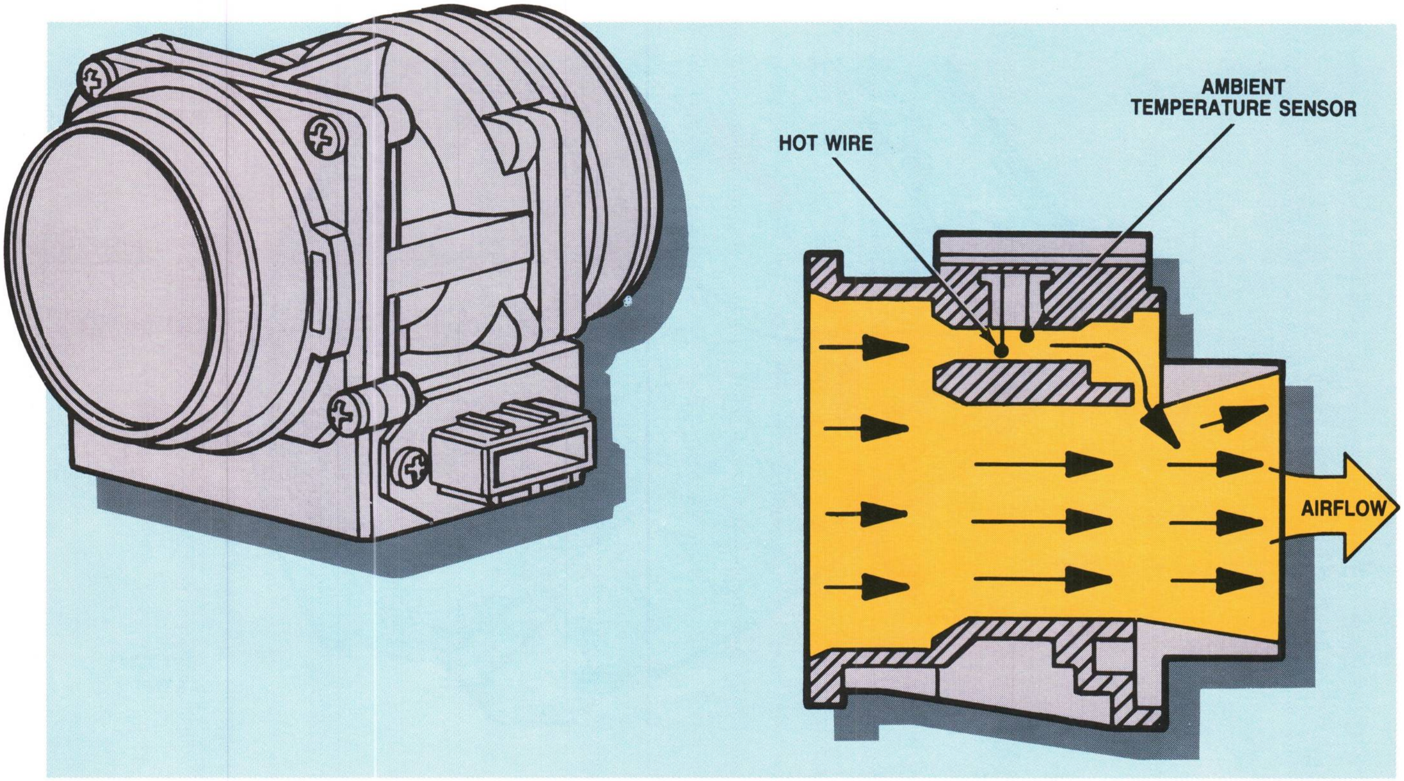
VANE METER

On some multi-point fuel injection systems that use mass airflow for fuel adjustment, a vane airflow (VAF) sensor is required. The VAF sensor is an integral part of the vane meter and measures the volume of air flowing through the meter. The sensor uses a moving vane connected to a potentiometer. The output of the meter is an analog voltage which has a relationship to the volume of the airflow. To obtain mass flow information, the airflow must be corrected for pressure and temperature variations. Temperature variations are monitored by the VAT sensor, which is also part of the vane meter as previously described. An external pressure sensor, such as the barometric pressure (BP) sensor, must be used for these calculations. Pressure sensors are covered later in this discussion.

MASS AIRFLOW SENSOR

On some mass airflow systems, a mass airflow (MAF) sensor is used to directly measure the mass of the air being drawn into the engine by volumetric displacement.

The mass airflow (MAF) sensor operates on the principle that if a mass is maintained at a constant temperature above ambient, the thermal loss is proportional to the mass flow of the cooling medium it is subjected to.



Mass Airflow Sensor

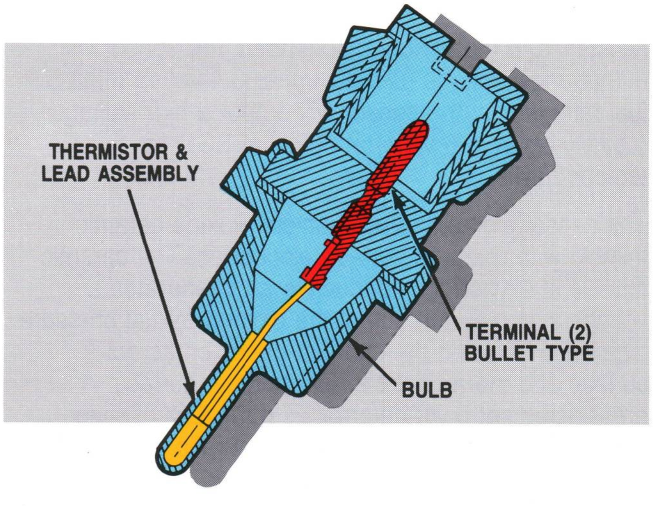
The internal electronics of the MAF sensor heat a wire element to 200°C (392°F) above ambient. The intake air stream tries to cool down the wire element. The MAF sensor applies more current to heat the wire and keep it at 200°C (392°F) above ambient. When a drop in the voltage required to heat the wire element occurs, the MAF outputs a signal to the ECA (0-5 volts) indicating the drop. The voltage drop is proportional to the flow of air mass across the wire element.

The lower the signal, the less airflow into the engine. The higher the signal, the greater the amount of airflow into the engine.

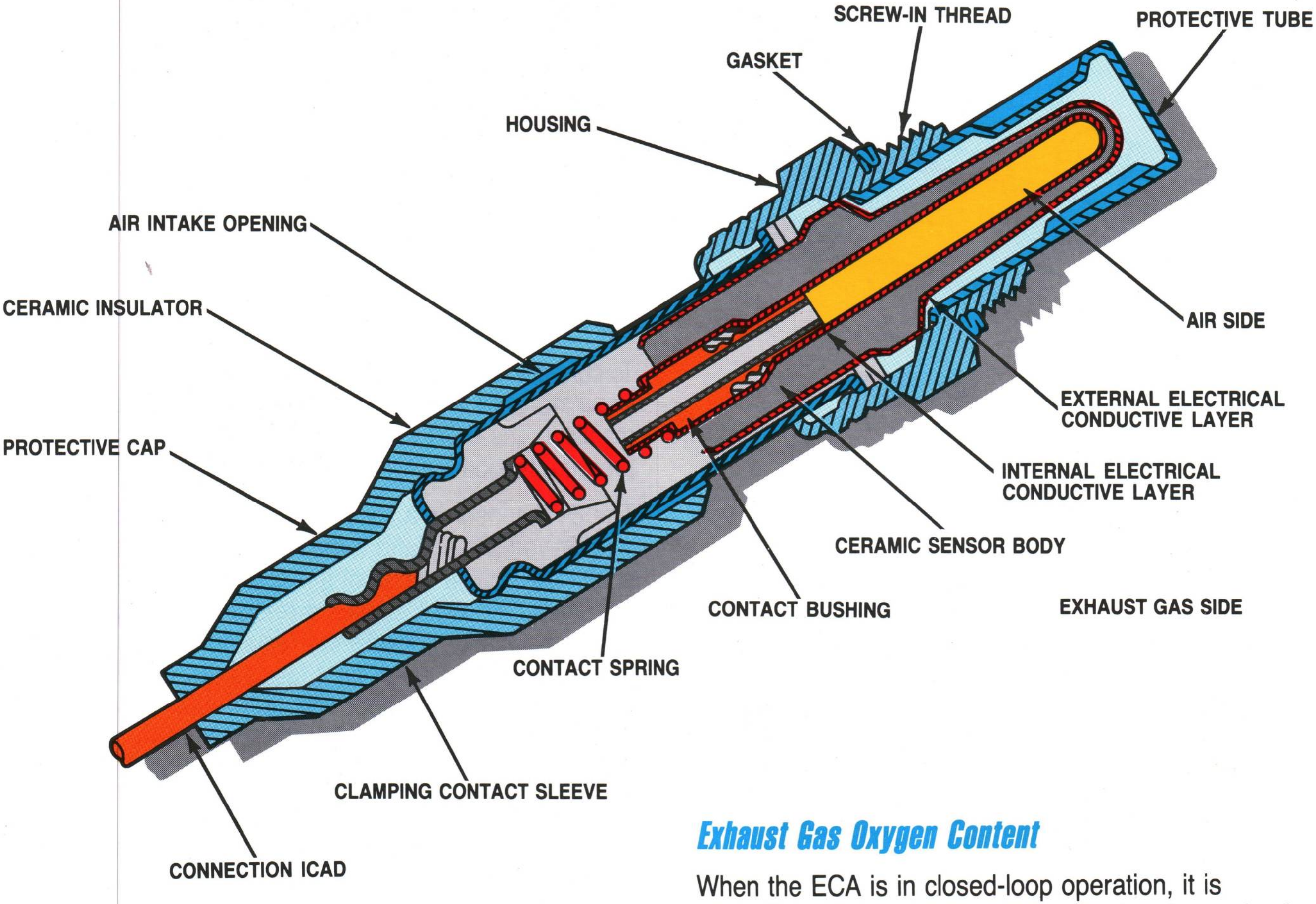
The MAF sensor is located between the air filter assembly and the throttle body.

Engine Coolant Temperature

Since the air/fuel ratio changes with the operating temperature of the engine, a sensor is needed to signal the ECA with engine coolant temperature information. The engine coolant temperature (ECT) sensor, threaded into the heater outlet fitting on the engine, is used for this purpose. The sensor element is a disc thermistor which changes its resistance with changes in temperature. The ECA applies a reference voltage to the ECT sensor and monitors the resultant output voltage produced by the resistance changes due to engine coolant temperature changes. As the coolant gets warmer, the voltage signal is increased.



Engine Coolant Temperature Sensor



Exhaust Gas Oxygen Sensor

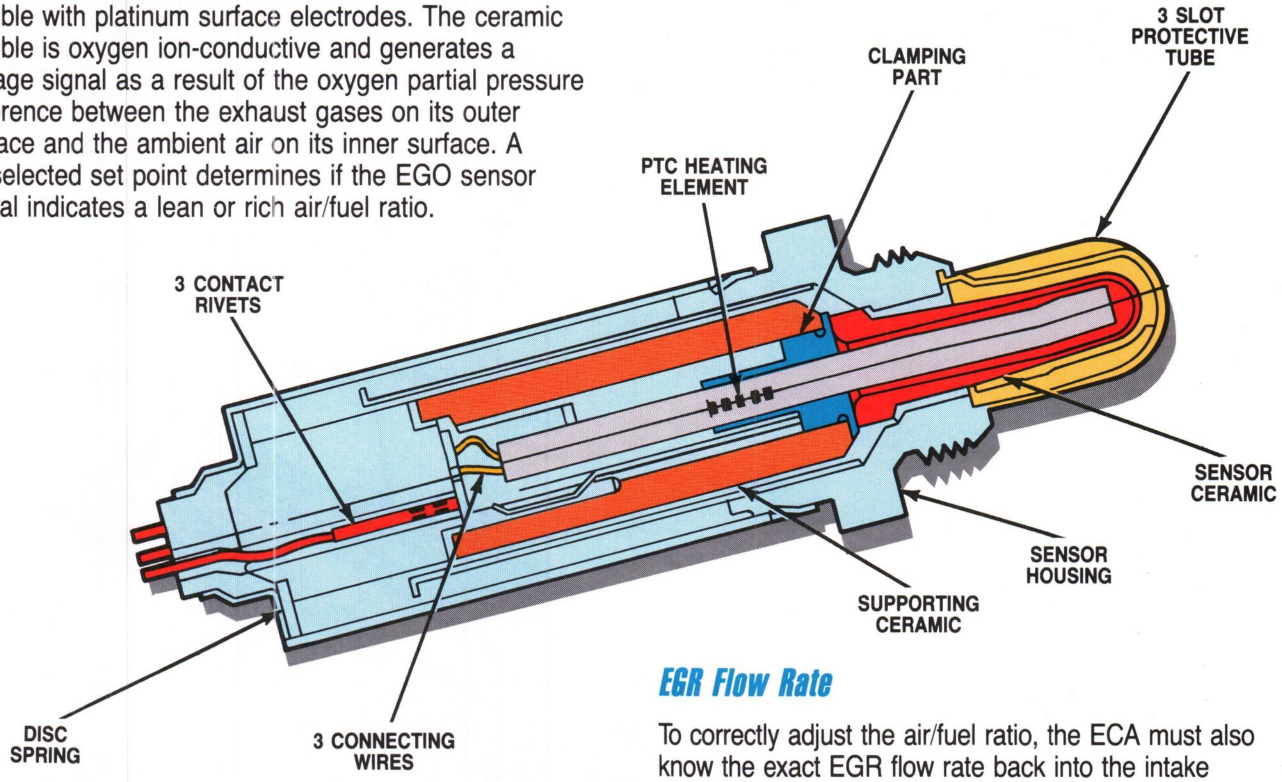
Exhaust Gas Oxygen Content

When the ECA is in closed-loop operation, it is controlling the fuel flow according to signals received from the exhaust gas oxygen (EGO) sensor. The EGO sensor is a device threaded into the exhaust manifold, so as to have its tip located in the exhaust stream. It provides a signal indicating whether the air/fuel ratio is lean or rich compared to stoichiometry. Stoichiometry is a technical term used to describe a perfect balance in the exhaust gas oxygen level.

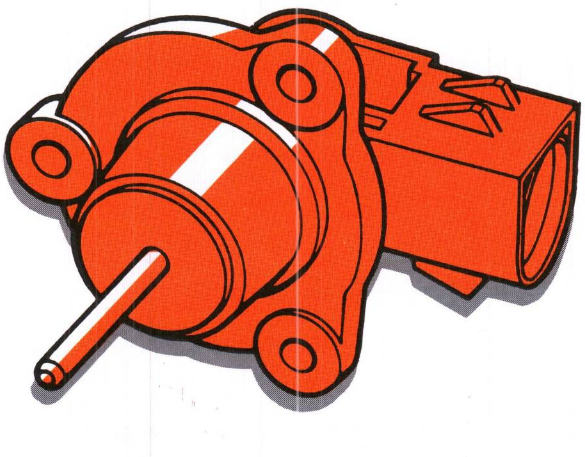
The EGO sensor acts as a voltage source and series resistance. If the air/fuel ratio is lean, the sensor will output a low voltage (usually under 0.4 volts). If the air/fuel ratio is rich, the sensor will output a high voltage (usually above 0.6 volts) at 662°F of EGO tip temperature.

The sensor element is a zirconium dioxide ceramic thimble with platinum surface electrodes. The ceramic thimble is oxygen ion-conductive and generates a voltage signal as a result of the oxygen partial pressure difference between the exhaust gases on its outer surface and the ambient air on its inner surface. A preselected set point determines if the EGO sensor signal indicates a lean or rich air/fuel ratio.

Some EGO sensors have battery voltage and a ground circuit to them. These sensors are called HEGO (heated exhaust gas oxygen) sensors. A HEGO sensor will obtain and stay at operating temperature faster than an EGO sensor.



Heated Exhaust Gas Oxygen Sensor



EGR Valve Position Sensor

EGR Flow Rate

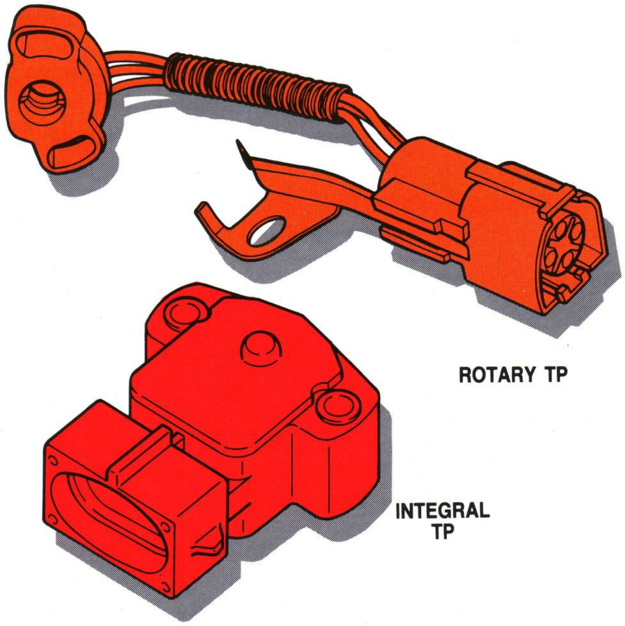
To correctly adjust the air/fuel ratio, the ECA must also know the exact EGR flow rate back into the intake manifold. The EGR valve position (EVP) sensor and the pressure feedback EGR (PFE) sensor serve this purpose.

The EVP sensor is a linear potentiometer consisting of a resistive element and a moving wiper mounted on a shaft. The usable range of the shaft travel is 0.00 to 0.50 inch. The ECA applies a reference voltage to the EVP sensor and monitors the resultant output voltage produced by the sensor as it follows the EGR valve pintle position. The output voltage produced is directly proportional to the position of the EGR valve pintle. This allows the ECA to determine the actual EGR flow at any point in time.

The pressure feedback EGR (PFE) sensor is a ceramic capacitive-type sensor that operates electrically, the same as a potentiometer. It converts exhaust system pressure or vacuum into an analog electrical input signal of 0.2-4.75 volts DC. A high-voltage signal output indicates minimum or no exhaust gas recirculation (EGR) flow. With the engine running at idle, an output signal of 3.25 +/− 0.25 volts DC is indicated.

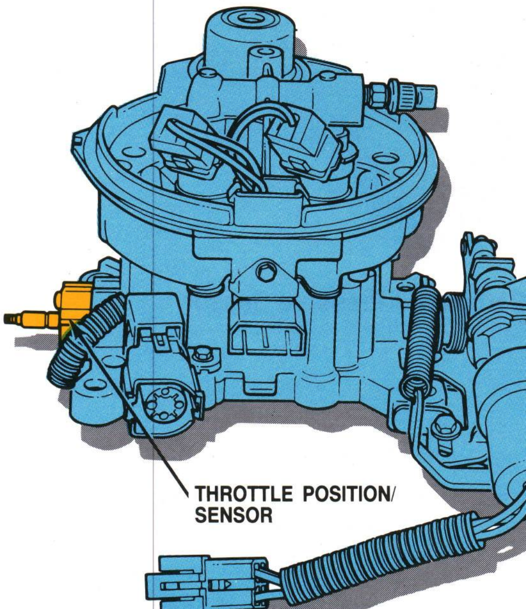
Throttle Position

In order for the ECA to determine driver demands, a sensor is needed to monitor the throttle position. A throttle position (TP) sensor is used to perform this function. The TP sensor is a potentiometer utilizing a variable resistive element packaged inside a plastic housing. The resistive element varies a reference voltage from the ECA, and the ECA then monitors the sensor output voltage to determine precise throttle position.



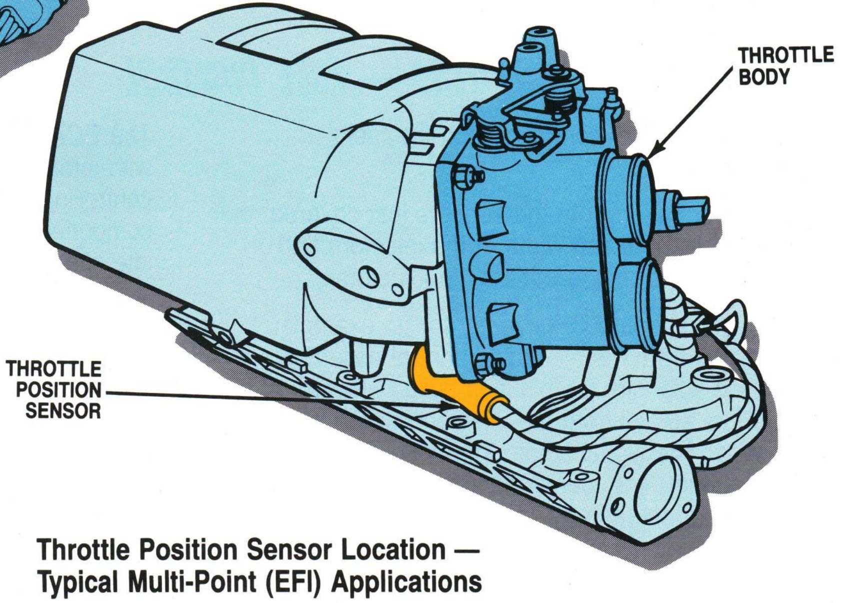
Typical Throttle Position Sensors

Throttle Position Sensor Location — Typical High Pressure CFI Applications



The TP sensor is mounted on the side of the fuel charging assembly, or throttle body, with the throttle shaft extending through the center of the sensor. The throttle shaft drives the rotary section of the sensor. The output signal is used by the ECA to determine one of the following three engine operating modes:

- Closed throttle (idle or deceleration)
- Part throttle (normal operation)
- Wide-open throttle (maximum acceleration)



Throttle Position Sensor Location — Typical Multi-Point (EFI) Applications

Manifold Absolute Pressure and/or Barometric Pressure

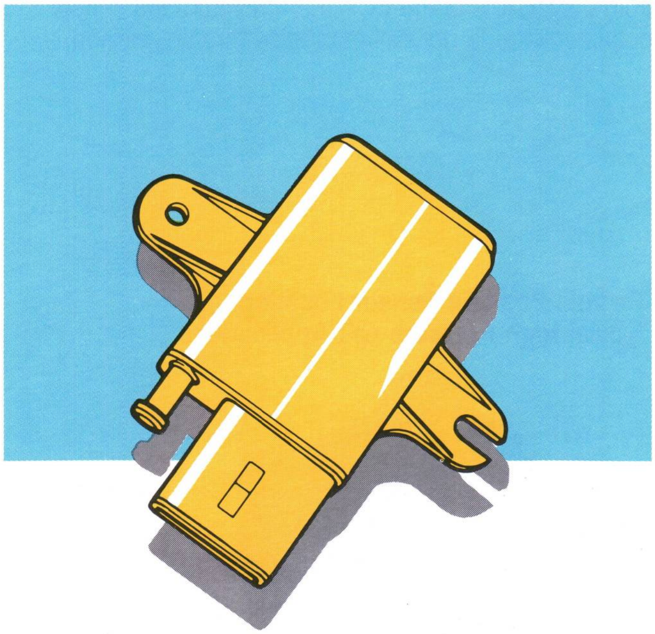
Since the oxygen content and the barometric pressure change with altitude, the ECA must have this information so it can compensate for these changes in the fuel flow into the engine. There are two different sensors used for this purpose: the barometric pressure (BP) sensor, and manifold absolute pressure (MAP) sensor.

The BP and MAP sensors each consist of a sensing element which is a capacitor. The capacitor has a vacuum reference which allows one of its surfaces (a diaphragm) to be partially deflected. Any change in pressure results in a corresponding change in the diaphragm deflection, and therefore, a change in capacitance. This capacitance change is converted to a frequency by the conditioning electronics.

The BP sensor senses changes in barometric absolute pressure, and is vented directly to the atmosphere. The BP sensor is used in mass airflow calculations, along with the VAT and VAF sensors.

The MAP sensor senses changes in manifold absolute pressure. It is connected by way of a vacuum hose to an intake manifold fitting. The MAP sensor senses barometric pressure during certain engine operating conditions, and updates the ECA as to the barometric pressure. These conditions are:

- Key on/Engine off
- Wide-open throttle acceleration — (zero vacuum conditions)



Barometric Pressure Sensor

ACTUATORS (ECA OUTPUTS) — FUEL CONTROL

There is only one fuel control output: the fuel injector output.

Based on information from the sensors just covered, the ECA calculates the pulse width of the injectors and outputs this as a signal to control the injectors.

Using the low pressure CFI injector for an example: When a signal from the electronic control assembly activates the solenoid, the pintle is pulled upward off its seat, and fuel sprays from the injector into the intake air stream. When the signal stops, the pintle moves back down to the seat, and fuel stops spraying. The ECA controls the air/fuel ratio by "pulsing" the injector on and off.

The ECA then makes computations and comparisons with information held in memory . . . and sends controlling output signals to the fuel injectors and other components to achieve the desired air/fuel ratio and idle speed.

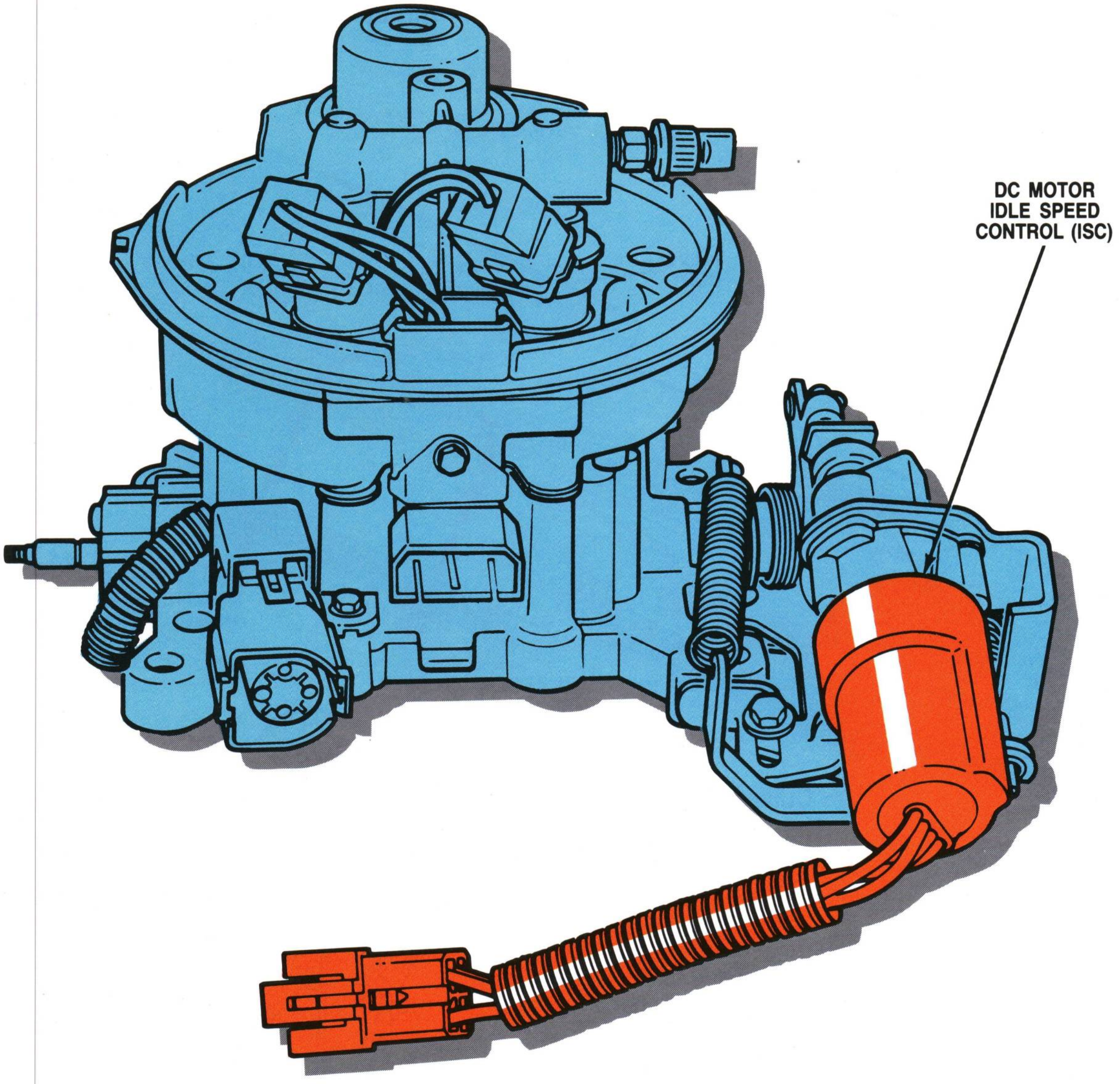
The ECA controls the air/fuel ratio on both EFI and CFI systems by varying the injector pulse width, that is, the amount of time the injector is open for each spray. A wide pulse width provides a rich air/fuel ratio. A narrow pulse width provides a lean air/fuel ratio.

IDLE SPEED CONTROL

CFI Systems

On the low and high pressure CFI systems, a DC motor idle speed control (ISC) regulates engine idle speed using a throttle lever with a plunger. By modulating the lever and plunger, the ISC controls airflow to maintain the desired engine rpm. This applies both to warm engine idle and to the additional engine speed required during cold engine idle.

An idle tracking switch, located on the end of the plunger, determines when the throttle lever has contacted the plunger, thereby signaling to the ECA the need to control engine rpm. The ISC extends (to increase idle speed) or retracts (to decrease idle speed) a plunger through a gear reduction system. The motor direction is determined by the polarity of the applied voltage. The ISC replaces the choke and throttle kicker to control idle speed, and also serves as an electronic dashpot, retracting (closing) the throttle at a predetermined speed during deceleration.

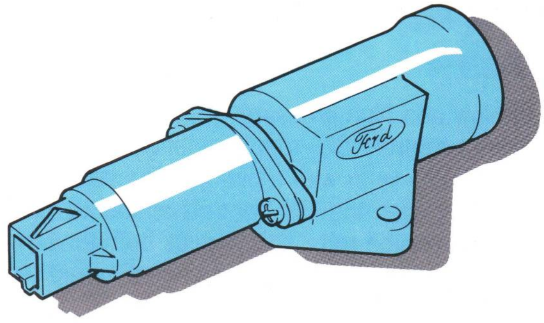


DC Motor Idle Speed Control

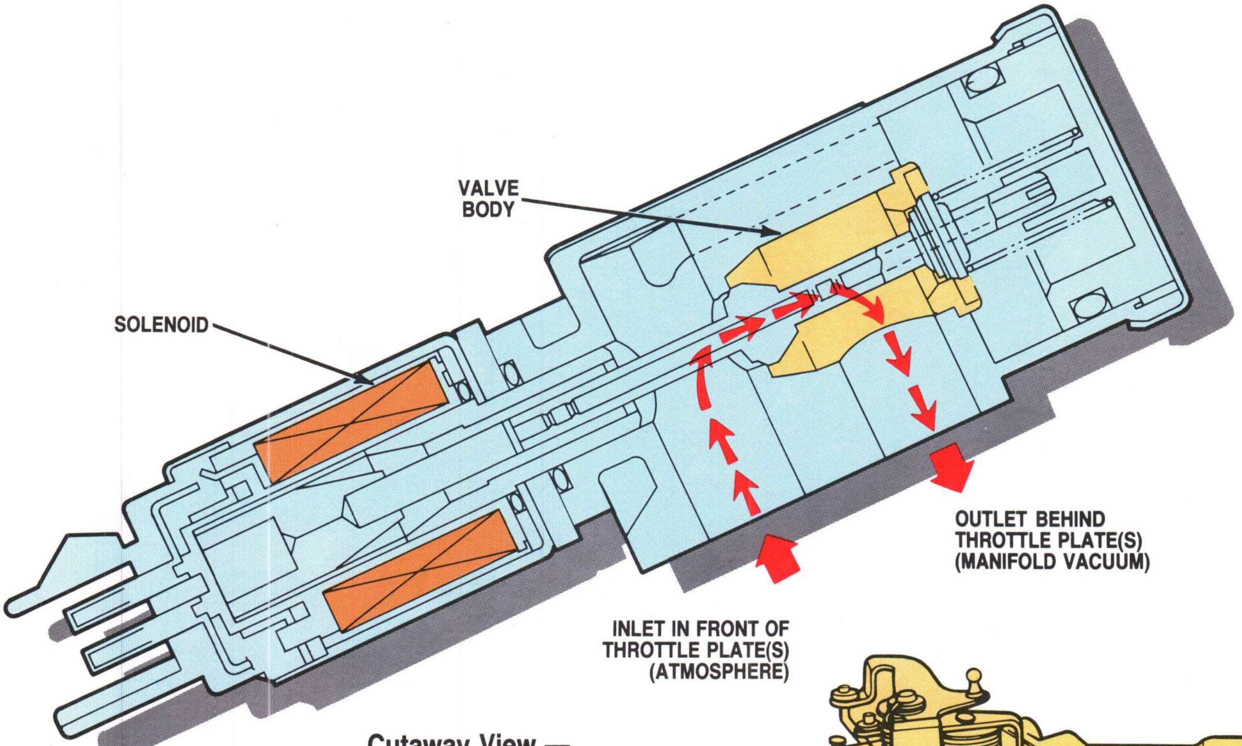
The ISC will pre-position for engine start-up when the engine is turned off. At engine shutdown the ISC plunger will retract, preventing engine dieseling, and then extend again to a pre-determined setting for the next engine start-up.

Multi-Point (EFI) Systems

To control engine idle speeds, both cold and warm, the multi-point systems use a throttle air bypass valve solenoid. This valve solenoid, which is attached to either the throttle body or air cleaner (depending on application), controls airflow that is bypassed around the throttle plate(s). With the throttle body-mounted valve solenoid, air enters the valve solenoid in front of the throttle plate(s), passes through the valve, and is bypassed behind the throttle plate(s). The air flows through internal passages located in the throttle body in front and behind the throttle plate(s).



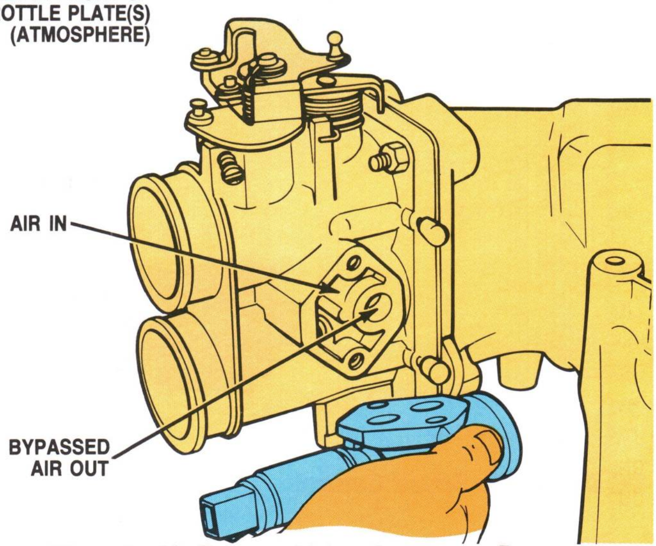
Throttle Air Bypass Valve Solenoid


VALVE BODY
SOLENOID
OUTLET BEHIND THROTTLE PLATE(S) (MANIFOLD VACUUM)
INLET IN FRONT OF THROTTLE PLATE(S) (ATMOSPHERE)

Cutaway View — Throttle Air Bypass Valve Solenoid

With the air cleaner-mounted throttle air bypass valve solenoid, air enters the valve solenoid at the air cleaner, passes through the valve, and then is directed by way of a hose to an inlet attached to the rear of the throttle body behind the throttle plate.

In both arrangements the valve solenoid is controlled by the ECA. The throttle air bypass valve solenoid takes the place of the choke and throttle kicker or ISC. It also acts as an electronically controlled dashpot by controlling bypassed air during deceleration.



Throttle Air Bypass Valve Solenoid Passages — Typical Multi-Point Throttle Body

Switches

The ECA receives information from other various sensors which have no direct relationship to fuel control, but do affect idle speed control.

IDLE TRACKING SWITCH

The idle tracking switch (ITS), used on low and high pressure CFI switches, is integral with the DC idle speed control (ISC). The ITS signals the ECA when the throttle is open (switch closed) and not in contact with the DC motor idle speed control plunger. The voltage signal to the ECA at this time is less than one volt. When the throttle lever is in contact with the plunger, the switch opens and a 12-volt signal is sent to the ECA.

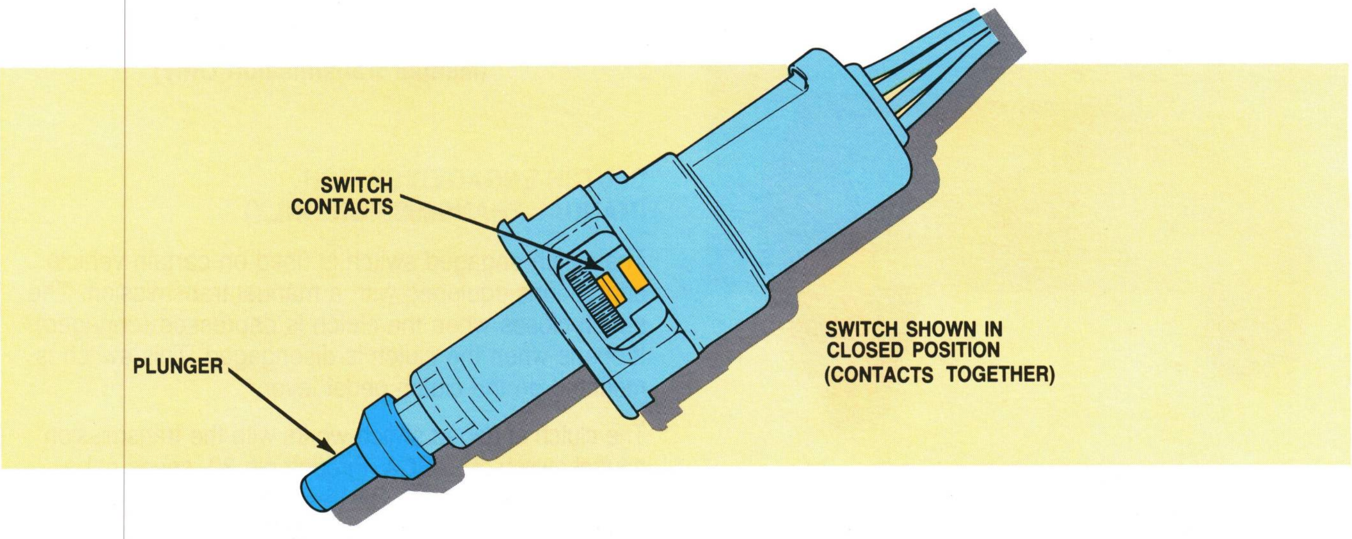
This allows the ECA to determine whether it should cycle the plunger completely out, or act as a dashpot to control engine idle speed.

NEUTRAL START SWITCH OR NEUTRAL DRIVE SWITCH (AUTOMATIC TRANSMISSION ONLY)

A signal indicating when the transmission is in NEUTRAL is required on certain applications. This helps the ECA determine the load on the engine (transmission in gear). A VREF voltage on the line (circuit 614) between the switch and pin 30 of the ECA indicates that the switch is open and the transmission is in DRIVE or REVERSE.

No voltage (one volt or less) on the line (switch closed) indicates that the transmission is in PARK or NEUTRAL.

The ECA adjusts the engine idle speed for the load or no-load conditions, and adjusts idle speed accordingly.



Idle Tracking Switch

POWER STEERING PRESSURE SWITCH

The power steering pressure switch (PSPS) is a normally closed pressure switch used on certain vehicle applications to signal, through circuit 330, to pin 30 of the ECA when power steering pressure exceeds a specified limit (400-600 psi). The ECA can then adjust idle speed to compensate for added load on the engine.

BRAKE ON/OFF SWITCH

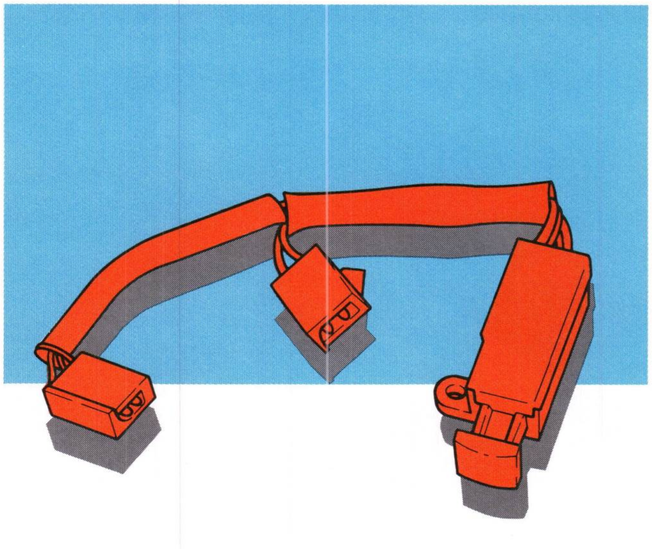
The brake ON/OFF (BOO) stoplamp switch is used on certain vehicle applications to signal, through circuit 511, to pin 2 of the ECA when the brake is applied. This signal allows the ECA to compensate for an engine idle condition. The ECA can alter the idle speed or turn off the A/C compressor if an extended idle is encountered with the brakes applied.

TRANSMISSION NEUTRAL SWITCH (MANUAL TRANSMISSION ONLY)

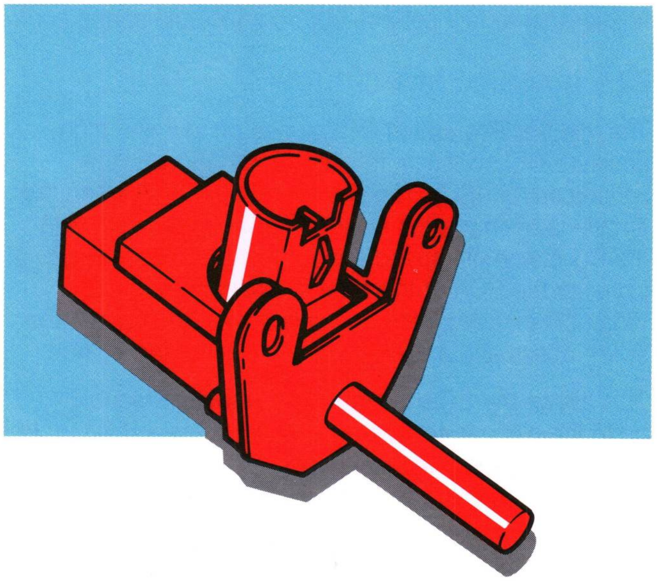
The transmission neutral switch is used on certain vehicle applications equipped with a manual transmission. The switch is closed only when the transmission is in the NEUTRAL position. The signal, through circuit 200 from the switch, indicates whether there is a load (transmission in gear) or no load (transmission not in gear) on the engine.

The ECA, through pin 30, sends out a 5-volt reference. When the switch is open, the ECA senses this 5 volts; but when the switch closes, the reference voltage drops to 1 volt or less.

This allows the ECA to determine if there is a load on the engine and adjust the idle speed accordingly.



Typical Clutch Engaged Switch (Manual Transmission Only)



Typical Neutral Switch (Manual Transmission Only)

CLUTCH ENGAGED SWITCH (MANUAL TRANSMISSION ONLY)

The clutch engaged switch is used on certain vehicle applications equipped with a manual transmission. The switch closes when the clutch is depressed (engaged). It opens when the clutch is disengaged. This switch is mounted on the clutch pedal lever.

The clutch engaged switch works with the transmission neutral switch. The ECA, through pin 30, sends out a 5-volt reference signal. This 5-volt signal is sensed by the ECA as long as the switch is open. When the switch closes, the reference voltage is dropped to 1 volt or less.

The ECA cannot tell if the clutch is depressed or if the vehicle is in NEUTRAL. It is only looking for a load or no-load condition. For example, if the clutch is not engaged (switch open) and the transmission is in NEUTRAL (switch closed), the reference voltage will still be dropped to 1 volt or less. This indicates that there is no load on the engine, and the ECA adjusts idle speed accordingly.

NEUTRAL PRESSURE SWITCH

The neutral pressure switch (NPS) is located inside the AXOD automatic transaxle. This switch is operated by hydraulic pressure inside the valve body. It signals the electronic control assembly (ECA), indicating whether the transaxle is in NEUTRAL or PARK, or in first, second, third or fourth gear. This helps the electronic control assembly (ECA) to determine the load on the engine (transaxle in gear), to adjust idle speed, and to determine when the transaxle is in fourth gear.

A reference voltage on the line is an indication that the switch is open and the transaxle is in NEUTRAL, PARK or fourth gear.

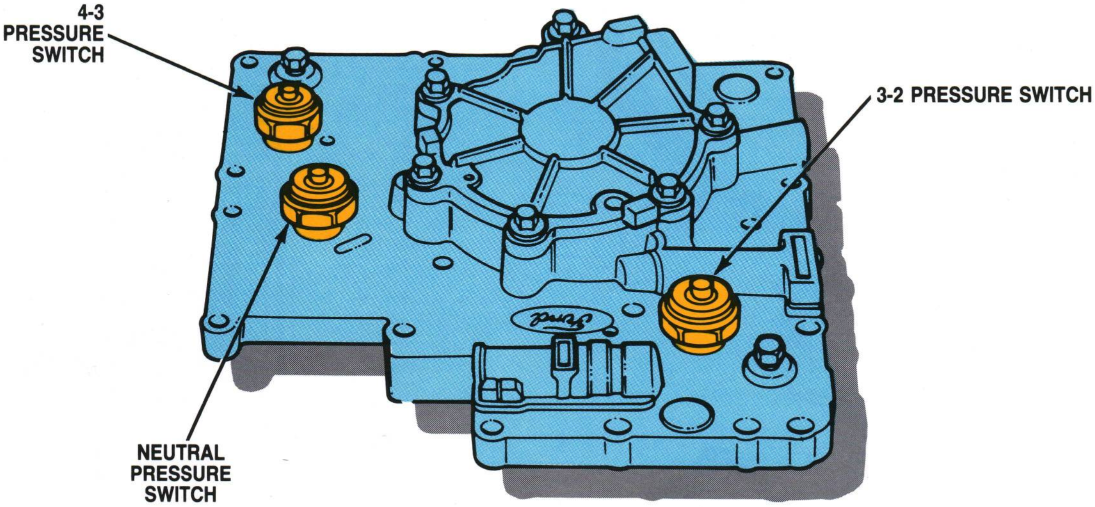
The neutral pressure switch (NPS) is unlike the neutral start switch because it supplies the electronic control assembly (ECA) with an indication as to when the transaxle is in fourth gear. The electronic control assembly (ECA) requires this information to help determine when the torque converter should be locked up.

A/C CLUTCH COMPRESSOR SIGNAL

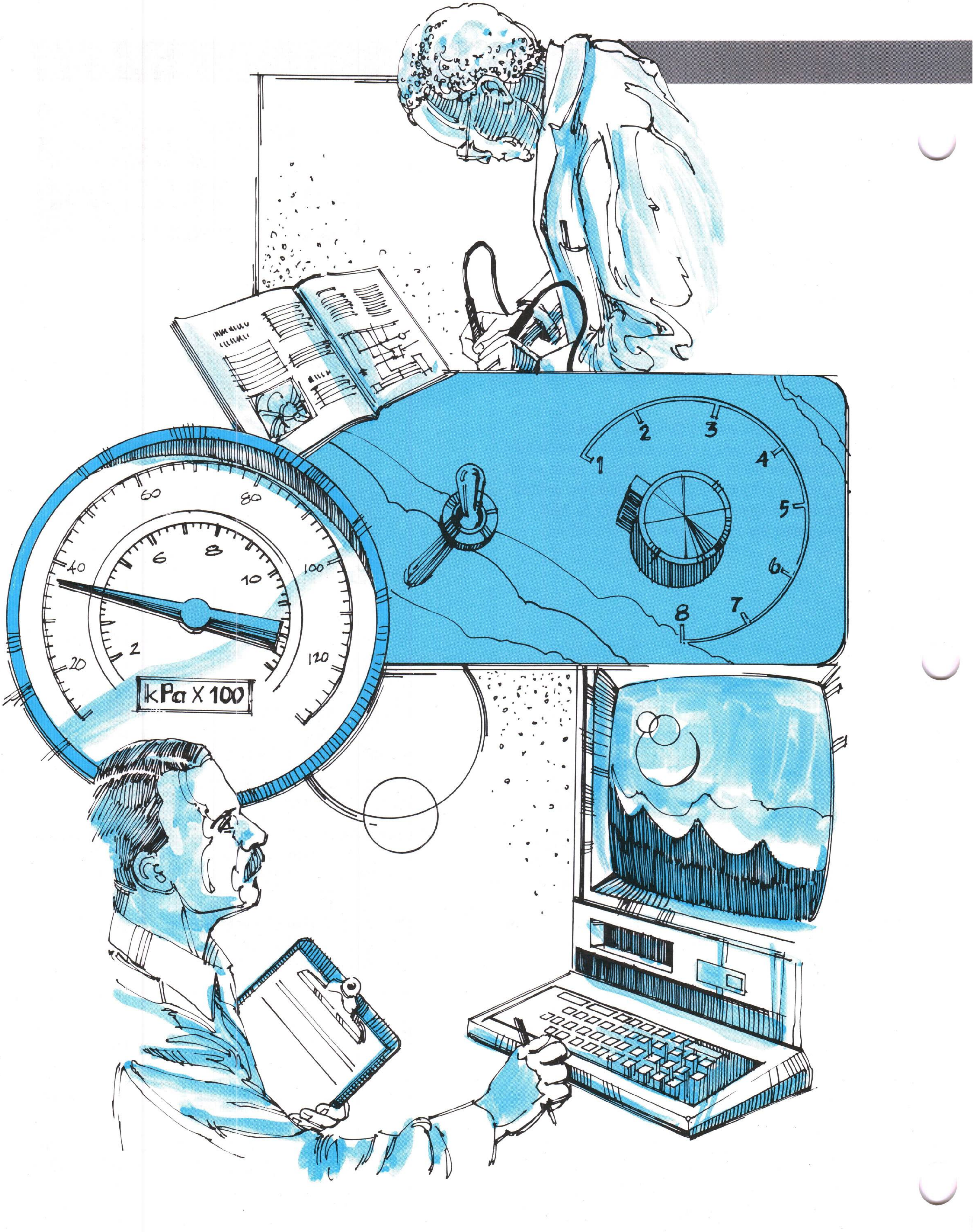
A signal, through circuit 347, is provided to pin 10 of the ECA when the A/C clutch compressor is turned on. This signal is used by the ECA to increase engine idle speed due to the load from the A/C compressor.

KEY POWER (KEY ON INPUT)

On applications with a DC motor idle speed control (ISC), when the "key on" signal is stopped, the ECA cycles the ISC plunger to prevent dieseling, and then extends it within 10 seconds for the next start-up.



Neutral Pressure Switch (AXOD Transaxle Only)


kPa X 100
20
40
60
80
100
120
2
6
8
10
1
2
3
4
5
6
7
8

DIAGNOSIS AND TESTING

When a vehicle is brought in for a driveability concern, you won't necessarily start by checking out the fuel injection system. Diagnosis of the fuel system is just one part of a good engine diagnosis that should be performed for any driveability symptom.

Always refer to Section 2 of the Engine/Emissions Diagnosis Manual, Volume H, to correctly diagnose any driveability concern.

INSPECTION

When Volume H directs you to check out the fuel injection system, a thorough visual inspection is the first step.

Start the vehicle inspection in the engine compartment. Perform the following inspection procedures:

> **NOTE**
>
> *On some CFI systems, the air cleaner assembly must be removed for inspection of the injectors, connectors and fuel pressure regulator.*

- For a "no start" condition, check the fuel pump to verify that it is running. On most vehicles you can hear the fuel pump running for approximately 1-2 seconds after the key is first turned to the ON position. If it is not running, check the inertia switch to see if it is set. If the pump does not run and the inertia switch is set, check for voltage to the inertia switch and to the fuel pump.
- Check the fuel lines and connections to be sure there are no leaks, the connections are secure, and the lines are in good condition.
- Check the fuel injectors to be sure they are seated properly in the lower intake manifold (multi-point systems).
- Check the fuel injector electrical connectors to be sure they are securely attached and that the connectors are not damaged or corroded.
- Check the fuel injection wiring harness for signs of damage or breaks in the insulation, and for secure connections at the throttle air bypass valve (multi-point system), DC motor idle speed control (CFI system) and the throttle position sensor.
- Check the throttle body, intake manifold (upper and lower manifolds on multi-point system), and fuel pressure regulator for cracks, loose attachments or any other signs of damage.
- Pull the vacuum hose off the pressure regulator (multi-point systems), and check for signs of gasoline or contamination. There should be no gas or contamination in the regulator or the hose.
- Operate the throttle linkage to be sure there is no sticking or binding.
- Check the air filter element for signs of cracks, tears, and excessive dirt. The air filter element should be replaced at scheduled maintenance intervals regardless of its appearance.
- Check the heated air system (if so equipped) for cracked or disconnected vacuum hoses, and for proper operation.

Perform the following inspection procedures under the vehicle:

- Check the fuel lines, filter and tank for signs of leakage.
- Check the fuel filter to be sure it has been replaced at scheduled maintenance intervals.
- Check the in-line fuel pump (if so equipped) and in-tank fuel pump, to be sure the fuel line and electrical connections are secure.

FUEL SYSTEM CHECKS

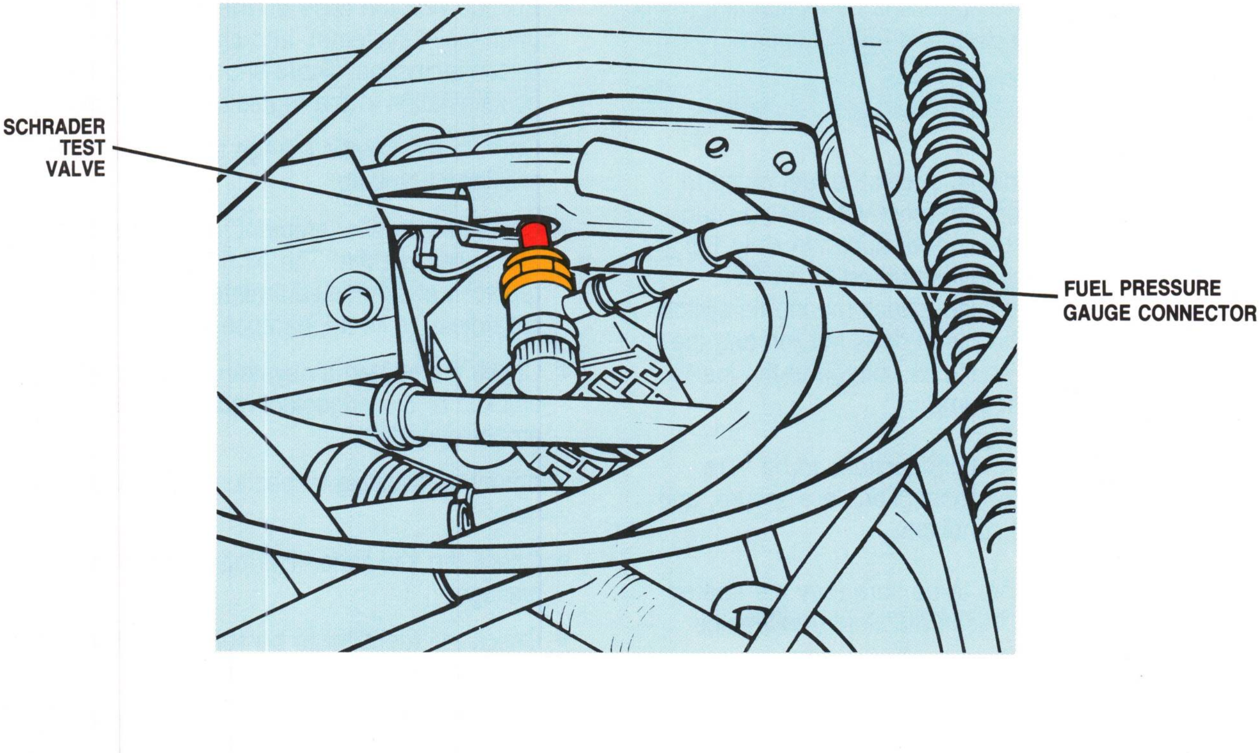
To operate properly, the fuel injection system must maintain a specified operating pressure and flow. Insufficient fuel pressure or flow can produce symptoms ranging from a "no start" condition to a lack of power, depending on how low the pressure falls.

Diagnosis of the fuel injection system includes checking fuel system pressure with a pressure gauge, and checking fuel flow.

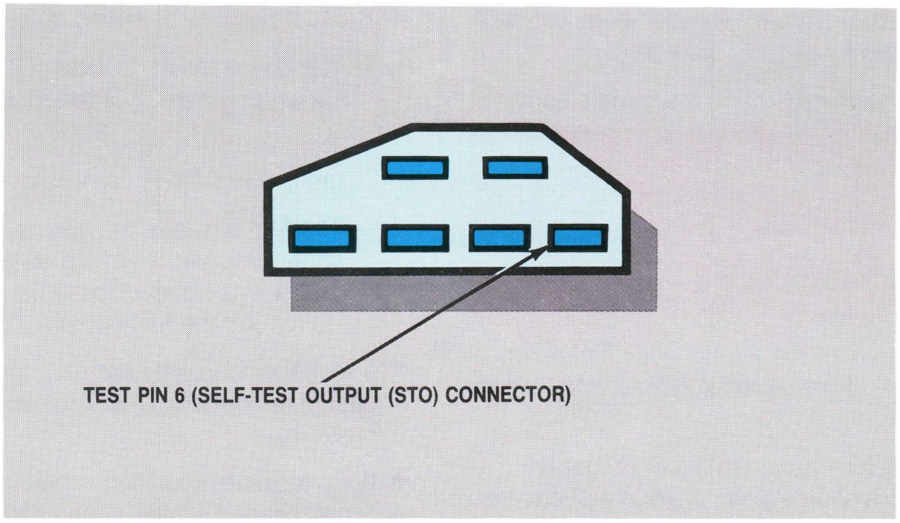
Pressure and Flow Test

Most fuel injection systems have a Schrader valve located on the fuel rail (multi-point systems) or on the throttle body (CFI systems). (For those applications where a Schrader valve is not on the vehicle, refer to Group 24 of the appropriate year Ford Shop Manual for procedures on how to check fuel system pressure.) On some vehicles equipped with the low pressure CFI system, a fuel pressure in-line Schrader valve adapter is available. This adapter connects in-line between the fuel supply line and the throttle body fuel inlet connection. Refer to the instructions that come with the pressure test gauge.

The procedures described here for testing fuel system pressure use Rotunda Special Tool T80L-9974-B (or equivalent). For vehicles without a Schrader test valve, there are two adapters available for this tool that add a Schrader valve to the fuel supply line for pressure testing: EFI/CFI Pressure Test Adapter D85L-9974-B for vehicles equipped with hair-pin-type fuel line connectors, and EFI/CFI Spring Lock Coupling Adapter D85L-9974-C for vehicles equipped with spring lock couplings on the fuel lines. A pressure gauge update is also available. This new gauge, D86L-9974-A, has a readout from 0-60 psi, and replaces the older gauge with a readout of 0-100 psi. This allows for a more accurate check of the low pressure fuel system, and still allows the gauge to be used on high pressure systems.



Fuel Pressure Gauge to Schrader Test Valve — Typical 2.3L EFI Turbo Engine Application



Pin 6 — Self-Test Output Connector

The following procedures are for vehicles equipped with multi-point fuel injection and a Schrader test valve:

- Attach the fuel pressure gauge to the Schrader test valve. Be sure it is securely tightened to prevent fuel leakage.
- Turn on the ignition switch and check the pressure gauge reading. Refer to the fuel pressure specifications in group 24 of the shop manual.
- Disconnect the fuel return line at the fuel rail.

WARNING

WHEN REMOVING FUEL LINES, USE CARE TO PREVENT COMBUSTION FROM FUEL SPILLAGE.

- Connect the hose from the fuel rail fitting to a calibrated container of at least one liter (one quart).
- Install a test lead to pin 6 of the self-test output connector of the EEC system. Ground the test lead to run the fuel pump.
- Allow the fuel to drain from the return hose into the container, and observe the volume.
- The fuel pump is operating properly if:
  - — The fuel pressure is within the specifications shown in group 24 of the shop manual.
  - — The fuel flow is within the specifications shown in group 24 of the shop manual.
  - — The fuel pressure remains within specification, as shown in group 24 of the shop manual, after the test lead is removed from the ground connection (to turn off the fuel pump).
- If all three conditions are met, the fuel pump is operating normally. Check for engine and electrical problems.
- If the pressure condition is met but the flow condition is not, check the filter(s) and fuel supply lines for blockage. Remove any blockages and recheck per above procedure. If the flow condition is still not met, replace the fuel pump.
- If both the pressure and flow conditions are met, but pressure is not maintained after the fuel pump is turned off, check the injectors and regulator for leaks. If both check out OK, replace the fuel pump.
- If no flow or pressure is seen, check the filter(s) and fuel supply lines for blockage. Remove any blockages and recheck per above procedure. If there is still no flow or pressure, replace the fuel pump.

The following procedures are for vehicles equipped with CFI fuel injection and a Schrader test valve:

- Disconnect the return fuel line at the throttle body.

WARNING

WHEN REMOVING FUEL LINES, USE CARE TO PREVENT COMBUSTION FROM FUEL SPILLAGE.

- Connect the hose from the throttle body fuel return fitting to a calibrated container of at least one liter (one quart).
- Attach a fuel pressure gauge to the Schrader test valve. Be sure it is securely tightened to prevent fuel leakage.
- Install a test lead to pin 6 of the self-test output connector of the EEC system. Ground the test lead to run the fuel pump for 10 seconds.
- Allow the fuel to drain from the return hose into the container, and observe the volume.
- The fuel pump is operating properly if:
  - — The fuel pressure is within the specifications shown in group 24 of the shop manual.
  - — The fuel flow is within the specifications shown in group 24 of the shop manual.
  - — The fuel pressure remains within specification, as shown in group 24 of the shop manual, after the test lead is removed from the ground connection (to turn off the fuel pump).
- If all three conditions are met, the fuel pump is operating normally. Check for engine and electrical problems.
- If the pressure condition is met but the flow condition is not, check the filter(s) and fuel supply lines for blockage. Remove any blockages and recheck per above procedure. If the flow condition is still not met, replace the fuel pump.
- If the flow condition is met but the pressure condition is not, check the pressure regulator valve on the throttle body for damage or wear.
- If both the pressure and flow conditions are met, but pressure is not maintained after the fuel pump is turned off, check the injector(s), and/or pressure regulator valve for leaks. If both check out OK, replace the fuel pump.

The following procedures are for vehicles equipped with CFI fuel injection and no Schrader test valve:

- Disconnect the inertia switch electrical connector.
- Crank the vehicle for a minimum of 15 seconds to reduce fuel pressure in the lines.
- Disconnect the fuel return line at the throttle body. Use care to avoid spillage.

WARNING

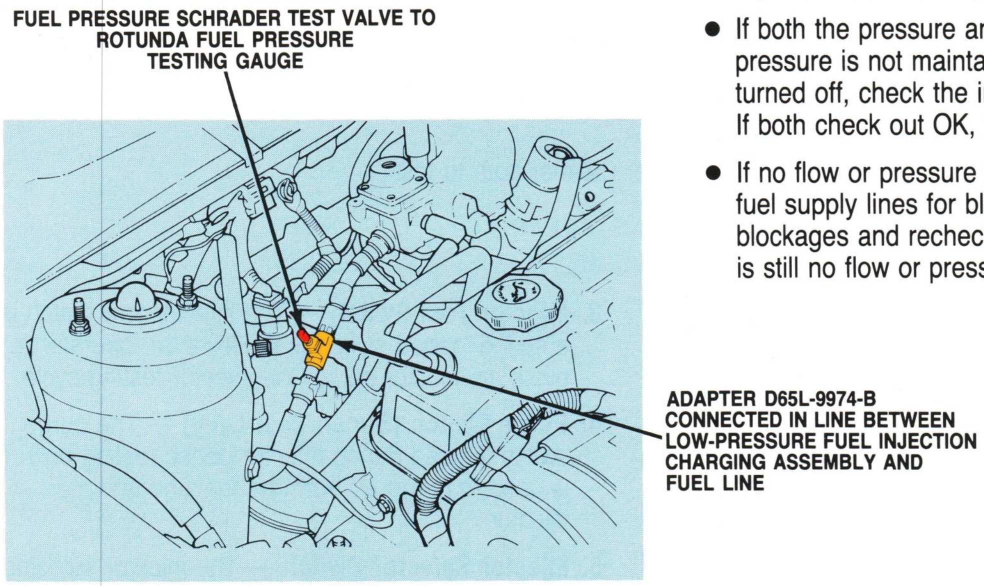
WHEN REMOVING FUEL LINES, USE CARE TO PREVENT COMBUSTION FROM FUEL SPILLAGE.

- Connect the hose from the fuel return fitting to a calibrated container of at least one liter (one quart).
- Disconnect the fuel supply line at the throttle body.

CAUTION

The fuel system contains pressurized fuel after the vehicle is shut down and will maintain this pressure for a long period of time.

- Install the pressure gauge adapter between the throttle body and the fuel line.


FUEL PRESSURE SCHRADER TEST VALVE TO ROTUNDA FUEL PRESSURE TESTING GAUGE
ADAPTER D65L-9974-B CONNECTED IN LINE BETWEEN LOW-PRESSURE FUEL INJECTION CHARGING ASSEMBLY AND FUEL LINE

Low Pressure CFI Fuel Pressure Test Adapter Hookup

- Attach a fuel pressure gauge to the Schrader test valve located on the pressure gauge adapter. Be sure it is securely tightened to prevent fuel leakage.
- Install a test lead to pin 6 of the self-test output connector of the EEC system (Fig. 69). Ground the test lead to run the fuel pump.
- Allow the fuel to drain from the return hose into the container and observe the volume.
- The fuel pump is operating properly if:
  - — The fuel pressure is within the specifications shown in group 24 of the shop manual.
  - — The fuel flow is within the specifications shown in group 24 of the shop manual.
  - — The fuel pressure remains within specification, as shown in group 24 of the shop manual, after the test lead is removed from the ground connection (to turn off the fuel pump).
- If all three conditions are met, the fuel pump is operating normally. Check for engine and electrical problems.
- If the pressure condition is met but the flow condition is not, check the filter(s) and fuel supply lines for blockage. Remove any blockages and recheck per above procedure. If the flow condition is still not met, replace the fuel pump.
- If both the pressure and flow conditions are met, but pressure is not maintained after the fuel pump is turned off, check the injectors or regulator for leaks. If both check out OK, replace the fuel pump.
- If no flow or pressure is seen, check the filter(s) and fuel supply lines for blockage. Remove any blockages and recheck per above procedure. If there is still no flow or pressure, replace the fuel pump.

FUEL PRESSURE REGULATOR TEST

As previously described, multi-point fuel injected vehicles use a pressure regulator with a vacuum port located on its top housing. The following test procedures are for this type of pressure regulator.

- Remove the fuel tank cap.
- Install a fuel pressure gauge at the Schrader test valve on the fuel rail.
- Start the engine, and run it for 10 seconds.
- Turn the engine off for 10 seconds.
- Repeat the above two steps.
- Remove the vacuum line at the fuel pressure regulator.
- Notice whether fuel exits the regulator at the vacuum port. If fuel does exit the vacuum port, replace the fuel pressure regulator and check the engine oil for contamination.
- Reconnect the vacuum line to the fuel pressure regulator.
- Start the engine and run it for 30 seconds.
- Turn the engine off.
- Observe the fuel pressure gauge. The fuel pressure should not drop more than 34 kPa (5 psi) after 60 seconds. If the pressure does drop more than 34 kPa (5 psi), check for line leaks (both vacuum and fuel).
- Relieve the pressure in the fuel rail.
- Remove the fuel pressure regulator.
- Inspect the gasket and O-ring for cracks, cuts or any other type of damage.
- Connect the vacuum gauge to the fuel return tube.
- Apply 20 inches Hg. of vacuum.
- The vacuum must not drop below 10 inches Hg. in 10 seconds. If vacuum does drop more than 10 inches of Hg. in 10 seconds, replace the fuel pressure regulator.

ROTUNDA FUEL INJECTOR TESTER/CLEANER

In some cases, diagnosis of the fuel injection system may lead to you to suspect that there is something wrong with the fuel injectors. For example, if the vehicle has a symptom such as missing or lack of power, and you know that the owner has been using dirty fuel, you would have good reason to suspect that one or more of the fuel injectors may be clogged with dirt from the fuel.

In these cases, you can use the Rotunda Fuel Injector Tester/Cleaner both to test injector operation, and to clean the injectors, if necessary.

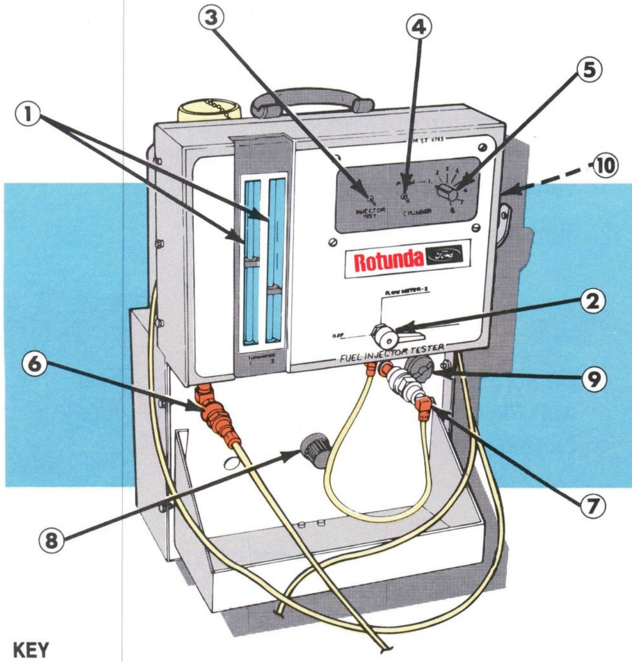
Description

The Rotunda Fuel Injector Tester/Cleaner contains the following components:

1. **Flowmeters** — The flowmeters display the amount of fuel flow through the injectors. The red balls show the actual fuel flow level, while the colored bars indicate the acceptable flow ranges for the different colored injectors used on Ford Motor Company vehicles.
2. **Flowmeter Selection Valve** — The flowmeter selection valve is used to select the correct flowmeter to be used when testing the injectors. Flowmeter 1 is used for blue, grey or yellow injectors; and Flowmeter 2 is used for white, black, green or brown injectors.
3. **Injector Test Switch** — The injector test switch is a spring-loaded switch that allows the operator to pulse an injector during the injector testing cycle.
4. **Purge Switch (Bench Test Only)** — The purge switch is used during injector bench testing only. It is used to purge air from the fuel line and the injector.
5. **Injector Selector Switch** — The injector selector switch is used to select the injector being tested during the injector testing cycle.
6. **Fuel Supply Outlet** — The fuel supply outlet supplies the injectors with pressurized fuel, by way of a fuel line, during the injector testing and cleaning cycles.

7. **Fuel Return Fittings and Return Line** — The fuel return fittings and return line allow fuel to recirculate through the machine.
8. **Fuel Regulator** — The fuel regulator is used to adjust fuel pressure supplied by the tester/cleaner during the testing and cleaning cycles.
9. **Manual Shutoff Valve** — The manual shutoff valve is used to allow fuel to recirculate inside the machine. With the valve in the OFF position, fuel does not recirculate inside the tester/cleaner. With the valve turned to the ON position, fuel recirculates in the tester/cleaner.
10. **Wiring Harness Connector** — The fuel injector test harness connects to this connector.
11. **Power Supply Line** — The power supply line connects to the vehicle's battery to supply power to the tester/cleaner.
12. **Fuel Tank** — The fuel tank is filled with fuel during the injector test cycle, and with fuel and injector tester cleaner during the cleaning cycle.
13. **Pressure Gauge** — The pressure gauge displays the pressure supplied by the tester/cleaner.
14. **ON/OFF Timer Switch** — The ON/OFF timer switch is used to turn the tester/cleaner on and off. It is a two position switch. When it is in the ON position, the machine will run for approximately 10 minutes and then shut off automatically.
15. **Indicator Light** — The indicator light glows steadily when the unit is on, and flashes when the unit is off. The power supply line must be attached to the vehicle's battery for the light to work.
16. **Continuous Fuel Injector Switch, K-Jetronic Type** — This switch is not used on Ford fuel injection systems.

Included along with the tester/cleaner are a number of hoses and adapters. These hoses are the fuel supply hoses, and the flowmeter test hoses, which can be connected to the vehicle. Also included are a turnbuckle, which must be attached to the throttle linkage for idle speed adjustment; a continuity checker, for checking the continuity of the fuel injector harness connectors; an injector bench test fixture, which holds the injector during bench testing; and two injector harnesses: One harness, with eight injector connectors, is used on all applications except 5.0L SEFI applications. The other harness, with a 10-pin connector, is used on 5.0L SEFI applications.

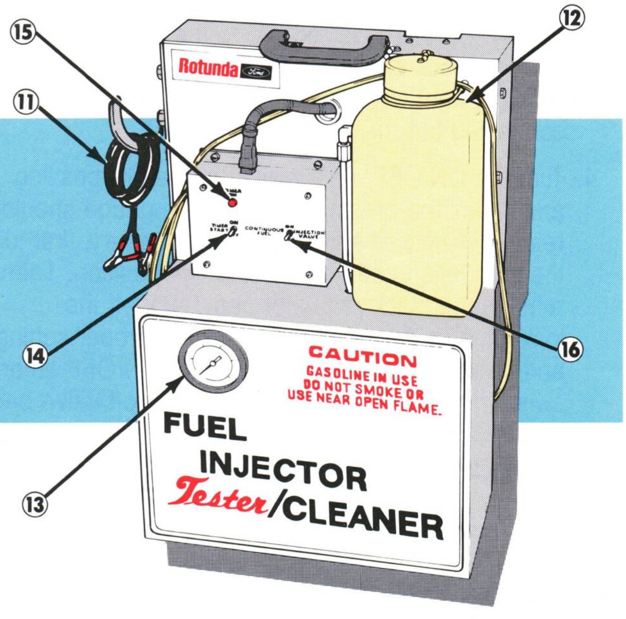


KEY

——→ SHOWS ACTUAL COMPONENT

– –→ SHOWS LOCATION OF COMPONENT

Rotunda Fuel Injector Tester/Cleaner Component Identification



Rotunda Fuel Injector Tester/Cleaner Component Identification

Fuel Injector Testing

WARNING

No smoking or other open flame or spark is allowed when working with the rotunda fuel injector tester/cleaner.

The fuel injection system operates at a high pressure. Never disconnect any fuel line or system component without first relieving the system pressure as described in group 24 of the shop manual.

1. Ensure that the manual shutoff valve is turned to the OFF position. If it is not, turn it to the OFF position.
2. Add clean, filtered, unleaded gasoline to the tester/cleaner tank. A paint filter can be used to filter the fuel as it is poured into the tank. For eight cylinder vehicles, fill the tank to the lower fill line. For four and six cylinder vehicles, fill the tank to a level a little below the lower fill line.

NOTE

No cleaning solvent should be in the tester/cleaner tank during injector testing.

3. Connect the battery supply line to the vehicle's battery. Connect the red clip to the positive terminal and the black clip to the negative terminal. The indicator light will flash to show that power is connected but the tester/cleaner is off.
4. Turn the ON/OFF timer switch to the ON position and check the pressure gauge. The gauge should read 38-40 psi. If adjustment is necessary, first turn the manual shutoff valve to the ON position. Then remove the black regulator cap, back off the locknut, turn the screw to obtain the proper setting, and re-tighten the locknut. Turn the ON/OFF timer switch off. Then, turn the manual shutoff valve back to the OFF position.
5. Connect the fuel supply hose to the fuel supply outlet and place the other end of the hose back into the tester/cleaner fuel tank.

NOTE

Use the proper hose for the vehicle being worked on. Compare the fittings on the end of the fuel supply hose with the fitting on the vehicle being tested.

6. Turn the ON/OFF timer switch on and turn the flowmeter selection valve first to flowmeter #1, and then to flowmeter #2. Repeat this procedure several times to eliminate all air bubbles from the system. Turn the ON/OFF timer switch off.

NOTE

The flowmeter selection valve must be in position #1 or #2 for the tester/cleaner to operate properly.

7. Remove the fuel supply hose from the tester/cleaner fuel tank and install the fuel tank cap snugly, then back it off one turn.
8. Follow shop manual procedures to remove the pressure from the vehicle's fuel system. Disconnect the engine fuel inlet connection at the fuel rail and connect the fuel supply hose from the tester/cleaner.
9. Disconnect the vehicle return line and plug the fuel return fitting at the fuel rail, using the appropriate plug supplied with the tester/cleaner.
10. Install the appropriate U-tube (supplied with the tester/cleaner) between the chassis supply line and the chassis return line.
11. Install the turnbuckle loosely between the throttle control rod or lever, and a convenient point on the vehicle fender well or dash panel.
12. Turn the ON/OFF timer switch on.

CAUTION

Be sure the vehicle is in PARK or NEUTRAL, with the parking brake applied and the wheels blocked front and rear.

13. Start the vehicle's engine and check the fuel lines for leakage. If there is any sign of leakage, turn the vehicle and the tester/cleaner off and repair the location where fuel is leaking. Then go back to Step 12.
14. When the engine speed has stabilized, set the idle speed at 2000 rpm with the turnbuckle. Run the remainder of the 10 minute cycle to eliminate all the air in the fuel supply hose and fuel rail.

15. With the tester/cleaner shut off (after 10 minutes), turn the ON/OFF timer switch back on and turn the vehicle's ignition switch to the OFF position.
16. Select the proper flow range by turning the flowmeter selection valve to either flowmeter #1 or #2, depending on the color of the injectors used on the vehicle.
17. Install the tester injector harness to the vehicle injectors. Match the injector number on the harness to that of the cylinder. (If the vehicle is a 5.0L SEFI, use the 10-pin connector injector harness.)
18. Position the injector selector switch to each injector number while pressing the fuel injector tester button.
19. Observe the red ball (float) in the flowmeter **at eye level** when the ball stops rising. A float level within the color code range on the scale indicates a good injector. **Flow readings slightly higher than the flow band after cleaning ARE ACCEPTABLE.**
20. To confirm the results of the test, **a maximum of three** tests can be performed on the set of injectors before restarting the engine.

NOTE

If the injectors test out OK and cleaning is not required, TURN THE MANUAL SHUTOFF VALVE TO THE ON POSITION before disconnecting the fuel system from the tester/cleaner. This will release any pressure in the fuel system.

INJECTOR TESTER RESULTS

- If the flowmeter readings are high or low on the color code scale, the fuel injectors should be cleaned.
- If all the readings are high, there may be leaky injectors (one or more). To check for leaky injectors, observe the pressure gauge. It should hold pressure with the fuel pump off. If there is a pressure drop, detect the leaky injector by observing the flowmeter. The leaky injector will show less flow. If this does not work, remove all injectors and test them individually in the bench test procedure.
- If fuel injector cleaning is required, refer to the injector cleaning procedure.
- Testing may be performed before or after the cleaning process.

Fuel Injector Cleaning

If the injectors do not show acceptable flow rates during testing, they should be cleaned.

1. Turn the manual shutoff valve to the ON position. If the tester/cleaner is already hooked up from the test cycle, proceed to Step 13; if not proceed to Step 2.
2. Add clean, filtered, unleaded gasoline to the tester/cleaner tank. A paint filter can be used to filter the fuel as it is poured into the tank. For eight cylinder vehicles, fill the tank to the lower fill line. For four and six cylinder vehicles, fill the tank to a level a little below the lower fill line.
3. Add injector cleaning solvent from the lower fill line to the upper fill line. If less gas is used as in the case of a four cylinder engine, use approximately 1 oz. of cleaner solvent to 7 oz. of unleaded gasoline.
4. Connect the battery supply line to the vehicle's battery. Connect the red clip to the positive terminal and the black clip to the negative terminal. The indicator light will flash to show that power is connected but the tester/cleaner is off.
5. Turn the ON/OFF timer switch to the ON position and check the pressure gauge. The gauge should read 38-40 psi. If adjustment is necessary, remove the black cap, back off the locknut, turn the screw to obtain the proper setting, and re-tighten the locknut. Turn ON/OFF timer switch off.
6. Connect the fuel supply hose to the fuel supply outlet and place the other end of the hose back into the tester/cleaner fuel tank.

NOTE

Use the proper hose for the vehicle being worked on. Compare the fittings on the end of the fuel supply hose with the fitting on the vehicle being tested.

7. Turn the ON/OFF timer switch on and turn the flowmeter selection valve first to flowmeter #1, and then to flowmeter #2. Repeat this procedure several times to eliminate all air bubbles from the system. Turn the ON/OFF timer switch off.

NOTE

The flowmeter selection valve must be in position #1 or #2 for the tester/cleaner to operate properly.

8. Remove the fuel supply hose from the tester/cleaner fuel tank and install the fuel tank cap snugly, then back it off one turn.
9. Follow shop manual procedures to remove the pressure from the vehicle's fuel system. Disconnect the engine fuel inlet connection at the fuel rail and connect the fuel supply hose from the tester/cleaner.
10. Disconnect the vehicle return line and plug the fuel return fitting at the fuel rail, using the appropriate plug supplied with the tester/cleaner.
11. Install the appropriate U-tube (supplied with the tester/cleaner) between the chassis supply line and the chassis return line.
12. Install the turnbuckle loosely between the throttle control rod or lever, and a convenient point on the vehicle fender well or dash panel.
13. Turn the ON/OFF timer switch on.

CAUTION

Be sure the vehicle is in PARK or NEUTRAL, with the parking brake applied and the wheels blocked front and rear.

14. Start the vehicle's engine and check the fuel lines for leakage. If there is any sign of leakage, turn the vehicle and the tester/cleaner off and repair the location where fuel is leaking. Then go back to Step 12.
15. When the engine speed has stabilized, set the idle speed at 2000 rpm with the turnbuckle, and run the remaining 10 minute cycle.
16. Turn the vehicle's ignition switch to the OFF position, and remove the turnbuckle.
17. Disconnect the fuel supply hose from the tester/cleaner to the vehicle.
18. **Drain and discard** the remaining mixture from the tester/cleaner fuel tank.
19. Turn the ON/OFF timer switch to the OFF position and disconnect the power supply line from the vehicle's battery.
20. Remove the plug from the vehicle's return outlet and remove the U-tube from the vehicle's fuel supply and return lines.

21. Install the vehicle's fuel supply and return lines to the fuel rail.

On 1983-1985 vehicles, use the new fuel connector retaining clips when reinstalling the vehicle fuel lines. LUBRICATE THE O-RINGS. Put a safety ring onto the fuel line connector when reinstalling the vehicle fuel line on late model vehicles equipped with the spring lock coupling connectors. The safety indicator ring will pop off when the connector is properly installed. Check for proper seating of the connection by using hand force to separate the connection so as to check for leaks.

22. Start the engine and check for fuel leaks.

After injector cleaning, you can retest the injectors to verify that they are operating properly.

Fuel Injector Bench Test

If a leaky injector is suspected, a fuel injector bench test can be performed. By observing the injector when it is not energized, and with fuel pressure applied to it, there should be no fuel leakage from the injector nozzle.

1. Ensure that the manual shutoff valve is in the ON position.
2. Fill the tester/cleaner fuel tank with several ounces of clean fresh, unleaded gasoline.
3. Connect fuel supply hose FA-402 to the fuel supply outlet, and to the injector bench fixture.
4. Select the proper flowmeter by turning the flowmeter selection valve to either flowmeter #1 or #2, depending on the color of the injector(s) to be bench tested.
5. Insert the injector to be tested into the injector bench test fixture.
6. Connect the #1 tester harness connector to the fuel injector. Turn the injector selector switch to the #1 position.
7. Direct the injector nozzle into the tester fuel tank.
8. Connect the power supply leads to the vehicle's battery. (Observe correct polarity, red lead to positive, black lead to negative.)
9. Turn the ON/OFF switch on, and check for fuel leaks.
10. At the same time, press the injector test switch and the purge switch for about 30 seconds to eliminate air from the supply hose and fuel injector.
11. Without the injector test or purge switch being pressed, there should be no fuel leakage from the fuel injector nozzle. If there is leakage, replace the injector.
12. Press the injector test switch to test the injector's flow. Observe the red ball (float) in the flowmeter.
13. Check the flowmeter readings and record all test results.

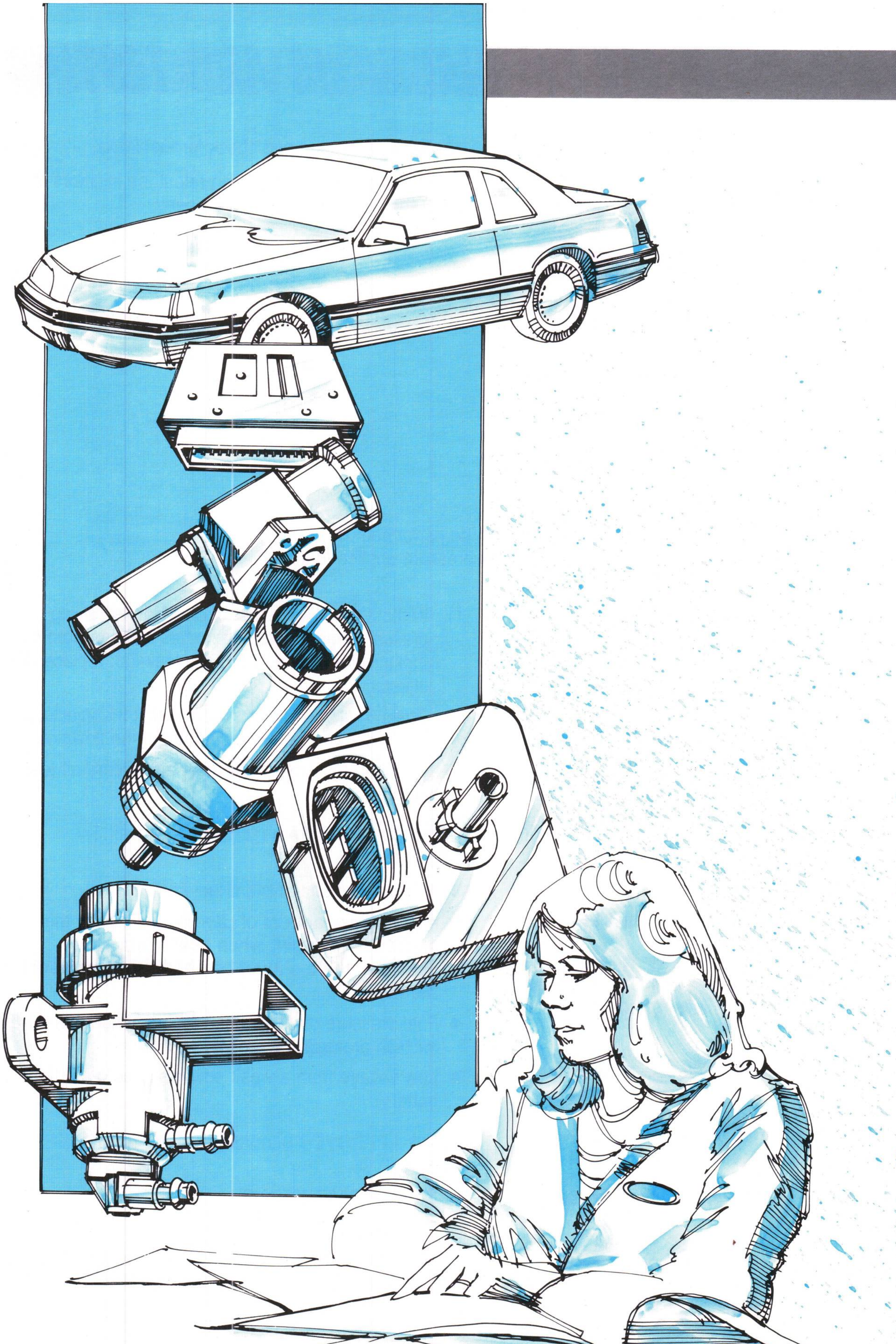
FACTORS THAT CAN CAUSE FALSE FLOW READINGS

- Air bubbles in the system fuel lines.
- An excessive amount of cleaning solution in the system. **Remember, when flow-testing the injectors, there should be no cleaning solvent in the fuel.**
- Fuel pressure other than the recommended 38-40 psi for high pressure fuel injected vehicles.
- Low voltage from a weak power source (vehicle's battery).

FORD-APPROVED SOLVENTS (USE ONLY THESE SOLVENTS)

- Part No. D9AZ-19579-B
- Part No. E6AZ-19579-C

For service or maintenance of the Rotunda Fuel Injector Tester/Cleaner, refer to the instructions that come with the tester/cleaner.



GLOSSARY OF TECHNICAL TERMS

ACT (AIR CHARGE TEMPERATURE) SENSOR — A thermistor type sensor (a sensor whose electrical resistance decreases with an increase in temperature) mounted in the intake manifold or air filter housing assembly, which signals the ECA with the temperature of air or air/fuel entering the engine.

ATMOSPHERIC PRESSURE — The pressure due to the weight of the earth's atmosphere, equal at sea level to approximately 14.69 psi.

ATOMIZATION — The reduction of a liquid to a fine spray.

BP (BAROMETRIC PRESSURE) SENSOR — A sensor or its signal circuit that sends a varying frequency signal to the ECA relating actual barometric pressure.

BRAKE ON/OFF (BOO) SWITCH — An input to the ECA indicating a braking drive mode.

CENTRAL FUEL INJECTION (CFI) — A type of fuel injection that uses one or two fuel injectors mounted in a centrally located fuel charging assembly, which is attached to an intake manifold. Can be either a low- or high-pressure system.

CLOSED LOOP — An electronic control circuit in which the output of the electronic control is measured by a sensor to signal the ECA whether the output is optimum or excessive.

CLUTCH ENGAGED SWITCH — A grounding switch that signals the ECA when the clutch pedal is depressed.

DC MOTOR IDLE SPEED CONTROL (ISC) — An actuator mounted to the fuel charging assembly which controls the idle speed. The ISC functions as high cam RPM, anti-diesel shutoff and dashpot, and pre-positions for the next vehicle start.

ECA (ELECTRONIC CONTROL ASSEMBLY) — The onboard computer that receives data from a number of sensors and other electronic components. Based on input data information programmed into the ECA's memory, the ECA generates output signals to control various engine functions.

ECT (ENGINE COOLANT TEMPERATURE) SENSOR A thermistor type sensor (a sensor whose electrical resistance decreases with an increase in temperature) that signals the ECA with the temperature of the engine coolant.

EEC (ELECTRONIC ENGINE CONTROL) — An electronic control of engine functions, such as fuel delivery, exhaust emissions, engine performance, etc.

EFI (ELECTRONIC FUEL INJECTION) — A type of fuel injection that uses a fuel injector for each cylinder. The injectors are mounted in the intake manifold just above the intake valve.

EGO (EXHAUST GAS OXYGEN) SENSOR — An oxygen-ion voltage generator (a sensor that generates a voltage signal as a result of the oxygen pressure difference between the exhaust gases on its outer surface and the ambient air on its inner surface) that supplies the ECA with a signal which represents the oxygen content of the exhaust gases. The ECA uses this signal to control the air/fuel ratio. On some applications the EGO sensor may be heated. The heating element allows the sensor to obtain operating temperature at a faster rate than a non-heated EGO sensor.

EGR (EXHAUST GAS RECIRCULATION) — A procedure where a small amount of exhaust gas is readmitted to the combustion chamber to reduce peak combustion temperatures and thus reduce NOx emissions.

GLOSSARY OF TECHNICAL TERMS

ELECTRIC FUEL PUMP — Three systems are used: High-pressure in-tank used for some high-pressure fuel injection systems; Low-pressure in-tank used for low-pressure fuel injection systems; Low-pressure in-tank/high-pressure in-line used for some high-pressure fuel injection systems.

ELECTRO-MECHANICAL — A mechanical device which is activated or controlled by electricity.

EVP (EGR VALVE POSITION) SENSOR — Potentiometric sensor or its signal line. Sensor wiper position is proportional to EGR valve pintle position. This allows the ECA to determine actual EGR flow at any point in time.

FREQUENCY — The number of periodic oscillations or vibrations expressed in cycles per second, and used by the MAP or BP sensor to signal the ECA.

ISC — See DC MOTOR IDLE SPEED CONTROL.

FUEL INJECTOR — A solenoid operated valve that meters fuel flow to the engine. The injector is opened and closed a constant number of times per crank revolution. The amount of fuel delivered is controlled by the length of time the injector is held open. The injector is normally closed and is operated by a signal from the ECA.

FUEL PRESSURE REGULATOR — A regulator which controls the fuel pressure to the fuel injectors. Used in both CFI (low- or high-pressure) and EFI systems.

FUEL RAIL ASSEMBLY — The assembly which connects the fuel lines to the fuel injectors. It also houses the fuel pressure regulator.

HALL EFFECT DEVICE — A device consisting of a semi-conductor material. When a constant current is passed through it and a magnetic field cuts the material at a right angle, a small separate voltage is generated on the opposite side of the semi-conductor. This small voltage is the output of the Hall effect device and is used in the PIP sensor.

LOWER INTAKE MANIFOLD ASSEMBLY — The lower manifold assembly, which is part of the fuel charging manifold assembly, which houses the fuel injectors.

MAF (MASS AIRFLOW) SENSOR — A sensor that measures the mass of the air flowing into the engine. This sensor is made up of a hot wire sensing element and an electronic circuit.

MAP (MANIFOLD ABSOLUTE PRESSURE) SENSOR
A frequency signal generator (a sensor which, when its capacitance changes, causes a frequency to change) that measures intake manifold pressure with a frequency and signals this information to the ECA. It will read barometric pressure with key On/engine Off and at wide-open throttle.

NEUTRAL PRESSURE SWITCH (NPS) — A grounding switch(es) for AXOD automatic transaxle only, that signals what gear the transaxle is in.

NEUTRAL START (OR DRIVE) SWITCH — A grounding switch that signals the ECA when manual transmission is in NEUTRAL.

OPEN LOOP — An electronic control circuit in which sensors provide information, the electronic control gives orders, and the output actuators obey the orders without feedback to the control.

PFE (PRESSURE FEEDBACK EGR) SENSOR — Ceramic capacitance pressure sensor that signals EGR flow. It measures pressure in the chamber below the EGR valve.

PIP (PROFILE IGNITION PICK-UP) SENSOR — A square wave signal generator (a device that converts a sine wave into a square wave) which supplies crankshaft position and RPM information to the ECA. This switch consists of a Hall effect device.

POWER STEERING PRESSURE SWITCH (PSPS) — An input to the ECA which is used to regulate engine idle speed based on power steering demand.

SEFI (SEQUENTIAL ELECTRONIC FUEL INJECTION)
A type of electronic fuel injection system in which each injector fires as the intake valve opens for that cylinder. See EFI.

SOLENOID — A wire coil with a moveable core which changes position by means of electromagnetism when current flows through the coil. Sometimes synonymous with "relay."

TFI-IV (THICK FILM IGNITION-IV) — An ignition system used on vehicles equipped with EEC-IV. This ignition system uses no vacuum or centrifugal advance. All advance is controlled by the ECA. It also uses an "E-Core" coil instead of an oil-filled coil.

THROTTLE AIR BYPASS VALVE SOLENOID — *Controls bypass of intake air around the throttle plate(s). Applied to multi-point fuel injection system only.*

TP (THROTTLE POSITION) SENSOR — *A rotary potentiometer (a sensor that varies its output voltage signal depending on its position in relationship to a variable resistor) which provides the ECA with a signal proportional to the opening angle of the throttle plate(s).*

TRANSMISSION NEUTRAL SWITCH — *A switch that signals the ECA when automatic transmission is in NEUTRAL.*

TURBOCHARGER — *A device using a turbine, driven by exhaust gases, to drive a compressor which compresses airflow into an engine, increasing horsepower.*

UPPER INTAKE MANIFOLD ASSEMBLY — *The upper manifold assembly, which is part of the fuel charging manifold assembly. The throttle body assembly mounts to this assembly.*

VACUUM — *The degree to which air pressure has been brought below atmospheric pressure.*

VAF (VANE AIRFLOW) SENSOR — *A sensor with a moveable vane, connected to a potentiometer, calibrated to measure the amount of air flowing through the sensor. The output signal is relayed to the ECA, which then translates the information into the amount of air flowing into the engine. Located in the vane meter.*

VAT (VANE AIR TEMPERATURE) SENSOR — *A sensor located in the vane meter which senses the temperature of the air flowing through the meter into the engine. Changes of temperature result in changes in a resistive element in the sensor.*

NOTES

ASE CERTIFIED™

WE SUPPORT VOLUNTARY TECHNICIAN CERTIFICATION

OCTOBER, 1987 LITHO IN U.S.A. ORDER NO. 2470-002